Supporting Information

Strategic Planning of the Integrated Urban Wastewater System using Adaptation Pathway Maps

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This document consists of 37 pages, 25 Tables and 30 Figures.

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S1. The terms defined or used in this paper

Table S1 (Part 1): The terms on adaptation and adaptation pathways defined and/or used in this study

Terms	Definition/description	Reference
Adaptation	Adaptation here refers to carrying out improvements on the drainage infrastructure, i.e. the engineering assets that normally define this type of systems.	Butler et al. (2017)
Adaptation strategies	Adaptation interventions considered in this study. These may be conventional grey infrastructure (i.e. sewer pipes, pumps, storage tanks and treatment facilities) as well as alternative green infrastructure (i.e. SuDS, BMPs).	This study
Adaptation thresholds	1. The points where changing conditions oblige a normally stable state of a system into another state or facilitate adaptation of the system (called also tipping points)	van Veelen et al. (2015)
	2. The points where the magnitude of changes (e.g. due to climate change) is such that the current strategy will no longer be able to meet objectives under different future scenarios (also called tipping points)	Kwadijk et al. (2010) and Renaud et al. (2013)
	3. The points at which threats exceed the system's ability to respond and recover (called recovery points)	van Veelen et al. (2015)
	4. The physical boundary conditions where acceptable technical, environmental, societal or economic standards may be compromised, requiring implementation of new actions to meet the specified objective (called also tipping points)	Manocha and Babovic, (2017)
	5. An adaptation limit as a point at which an action is no longer likely to be able to provide cost effective risk reduction, subject to social and environmental considerations (called also adaptation limit)	Kingsborough et al. (2016)
	6. The condition (or conditions) under which the current management strategy is no longer able to meet the clearly defined objective (or objectives) across a timeline; at this point, alternative adaptation strategies should be considered. Adaptation thresholds are used to evaluate the adaption domain size	This study
Adaptation domain	A set of possible future states or transient scenarios in which an adaptation strategy is compliance to the adaptation threshold or thresholds. The domain size of a strategy is identified using adaptation thresholds. The domain size is evaluated in two complementary ways: (i) the number of complying epochs across the scenarios and (ii) whether or not the pathways are uninterrupted (i.e. compliant) or interrupted (i.e. non-compliant) to one or more adaptation thresholds across the entire timeline	This study
Adaptation pathways	1. Alternative possible trajectories for knowledge, intervention and change, which prioritize different goals, values and functions	Leach et al. (2010)
	2. An analytical and foresight approach for exploring and sequencing a set of possible strategies along the planning timeline	Haasnoot et al. (2013)
	3. An approach that explores alternative sequences of investment decisions to achieve objectives over time in the context of uncertain future developments and environmental changes	Haasnoot et al. (2019)
	4. An approach that provides a visual representation of the potential sequencing and type of actions that may be implemented in the future.	(Kingsborough et al. 2016)
	5. A path (or series of paths) in which a strategy (or a combination of strategies) is compliant with the adaptation threshold(s).	This study

Table S1 (Part 2): The terms on adaptation and adaptation pathways defined and/or used in this study

Terms	Definition/description	Reference
Adaptation pathway map	This identifies possible pathways (or possible domain in different future states) along the planning timelines with respect to different adaptation thresholds	This study
Sell-by-date	1. The time when a strategy violates an adaptation threshold	Haasnoot et al. (2013)
	2. The period when a strategy option is expected to require adaptation or additional measures to be put in place due to an interruption of its satisfactory pathway of transient scenarios	van Veelen et al. (2015)
	3. The time epoch(s) when a strategy no longer achieves a set objective, when the compliant pathway of that specific strategy is interrupted	This study
Epochs or transient scenarios	Future scenarios at time intervals of every 5-years	This study

S2. Parameters used to distinguish different future scenarios from each other

The future scenarios differ from one another with respect to nine parameters (variables) indicative of various IUWWS uncertain conditions (Casal-Campos et al., 2018, 2015):

(1) Misconnections (L/s): the amount of misconnected foul sewers discharging into surface sewers was assumed to be related to existing regulations enforcing the identification of such misconnections as well as to the level of maintenance regimes required to undertake remedial reconnection work.

(2) Urban creep (ha): The level of urban creep happening in a scenario is a function of the level of regulations limiting the amount of uncontrolled re-surfacing of permeable areas as well as of the public willingness to implement decentralized surface water management measures that serve those new contributing areas. If both aspects were strong under a given scenario, the level of urban creep was therefore very low (Casal-Campos et al., 2015).

(3) Water use (L/head/day): Positive attitudes towards the decentralization of water management responsibilities had an influence in reducing domestic water use (e.g. facilitate demand-side measures), along with the role of regulations and water efficient technologies.

(4) Infiltration (L/s): infiltration of groundwater into sewers is assumed to be a consequence of both low sewer maintenance regimes and the unavailability of technological solutions to provide cost-effective maintenance.

(5) Siltation: As with infiltration, the degree of siltation is determined by the level of maintenance in the sewer infrastructure and the availability of technologies that facilitate such maintenance. .

(6) Population (inhabitants): population growth as an external threat is assumed to be independent of the internal uncertainties, since it is outside of the control of the IUWWS management. This parameter is defined according to the socio-economic conditions described in Casal-Campos et al. (Casal-Campos et al., 2015).

(7) CC precipitation uplift (%): the effect of climate change in rainfall intensity was considered independent of scenario conditions, since it was assumed that the sensitivity of precipitation predictions to different scenarios up to the year 2050 is modest, according to UK guidance (Kirtman et al., 2013).

(8) Impervious area in new developments (ha): Permeability changes were represented by the rate of urban creep occurring in the baseline catchment (i.e. loss of permeable area to impervious area in the original catchment) and by the increase in impervious area occurring as a consequence of urbanization (i.e. new developments) (Casal-Campos et al., 2015).

(9) Acceptability preference: acceptability of interventions under each scenario is assessed in terms of the preference for either centralized or decentralized options). These parameters were mostly linked to variations in catchment permeability and to the changes in sewer inflows, which could deteriorate system capacity in the future (Casal Campos, 2016; Casal-Campos et al., 2018).

Table S2: Parameter estimates affecting case conditions under each future scenario (adapted from Casal-Campos et al., 2018, 2015)

Parameter	Baseline	Markets	Innovation	Austerity	Lifestyles
Misconnections (L/s)	0	7.8	0.9	4.1	1.7
Urban creep (ha)	0	87.7	58.4	70.1	29.2
Water use (L/head/day)	155	165	125	140	110
Infiltration[1] (L/s)	52.4	163.7	40.5	200.1	135.5
Siltation[2]	0.97	0.92	1	0.84	0.92
Population (inhabitants)	181,000	262,450	244,350	217,200	226,250
CC precipitation uplift (%)	0	10	10	10	10
Impervious area in new developments (ha)	0	290.0	226.0	129.0	161.0
Acceptability preference[3]	C	C	C/D	D	D

1. It refers to infiltration of groundwater into the sewer system.
2. The effect of siltation, which represented system capacity loss in sewer pipes due to deposited sediment, was modelled as the corresponding reduction in pipe diameter under each scenario (corresponding to full-pipe area reduction); 1: no reduction, 0: full reduction.
3. The acceptability of interventions under each scenario is assessed in terms of the preference for either Centralized (C) or Decentralized (D) options. The Innovation scenario shows a mixed preference for centralized interventions, where decentralization is also promoted.

S3. Performance objectives and indicators

Table S3: Performance objectives and indicators used to define impacts and consequences (adapted from Casal-Campos et al. (2018)

Objectives	Reliability Indicators	Resilience Indicators	Sustainability Indicators
Sewer Flowing	% time free of flood	Summation of duration-weighted flood volumes [m^3]	Total flood volume [m^3]
River DO	% time *DO > 4 mg/l*	Summation of duration weighted DO minima [*mg/l*]	6-hour minimum dissolved oxygen [*mg/l*]
River AMM	% time AMM < *4 mg/l*	Summation of duration weighted AMM minima [*mg/l*]	99 percentile total ammonia [*mg/l*]
CSOs	% time not spilling	Summation of duration-weighted spill volumes [m^3]	Total spill volume [m^3]
River Flooding	% time free of flood	Summation of duration-weighted flood volumes [m^3]	Total flood volume [m^3]
GHG Emissions	-	-	Total operational emissions from pumping & treatment [tCO_2]
Costs	-	-	PV of whole-life costs [£]
Acceptability	-	-	Acceptability level of strategies [Low accept (L) = 1; Medium accept (M) = 2; High accept (H) = 3;

DO: Dissolved Oxygen; **AMM**: River Total Ammonia; **GHG**: Green House Gas

S4. Design considerations for hybrid strategies

S4.1 Attenuation volume of SCR and CST

Attenuation capacity of SCR (rain gardens):

Area removed is 34% of total area[A]:

$$758.9 \times 0.34 = 258 \text{ ha}$$

Assuming 20 mm of attenuation storage for rain gardens:

$$258 \text{ ha} \times 10{,}000 \ \frac{\text{m}^2}{\text{ha}} \times 20 \times 10^{-3} \text{m} = 51{,}600 \text{m}^3$$

This is comparable to the storage volume proposed for the CST strategy (50,000 m^3).

S4.2 Design of hybrid strategies

<u>50% of SCR strategy removes 17% of total area:</u> 758.9×0.17 = 129 ha

Annual rainfall in 2050: 683.4 mm

Annual volume managed by 50% of SCR:

$$129 \text{ ha} \times 10{,}000 \ \frac{\text{m}^2}{\text{ha}} \times 683.4 \times 10^{-3} \text{m} = 881{,}586 \text{ m}^3/\text{year}$$

<u>Fraction of OT (on-site wastewater treatment) to manage an equivalent volume:</u>

Average population increase in 2050 (mean growth across scenarios): 56,563[B]

Average population affected by OT in 2050: 28,282

Average water use in 2050: 135 L/h/day

Average wastewater volume managed by OT: 28,282×135×365 = 1,393,596 m^3/year

Fraction of OT required for managing the volume of 50% SCR [881,586 m^3/year]:

$$\frac{881{,}586}{1{,}393{,}596} = 0.63 \text{ (63\% of OT)}$$

<u>Fraction of SS to manage an equivalent volume:</u>

Average separate area managed by SS across scenarios in 2050: 323 ha

Annual volume managed on average by SS:

[A] typical value in UK terraced residential developments (Ward et al., 2012)

[B] Calculated in Casal-Campos et al. (2015)

$$323\ \text{ha}\times 10{,}000\ \frac{\text{m}^2}{\text{ha}}\times 683.4\times 10^{-3}\,\text{m} = 2{,}206{,}382\ \text{m}^3/\text{year}$$

Fraction of SS required for managing the volume of 50% SCR [881,586 m^3/year]:

$$\frac{881{,}586}{2{,}206{,}382} = 0.4\ (40\%\ \text{of SS})$$

S5. Results on different domains for single adaptation threshold

S5.1 Reliability domains for single adaptation threshold

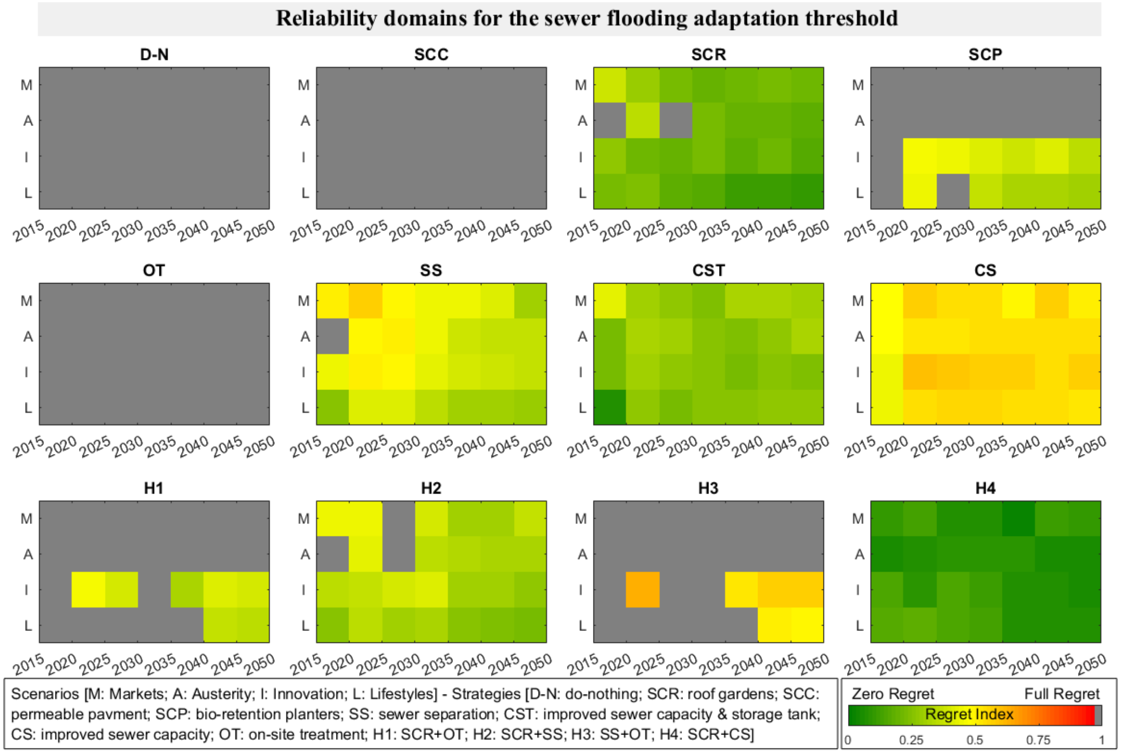

Fig. S1: Reliability domains for the sewer flooding adaptation threshold. The compliant domain (coloured tiles) ranges from low (green) to high regret (red). Non-compliant and full-regret tiles are shown in grey.

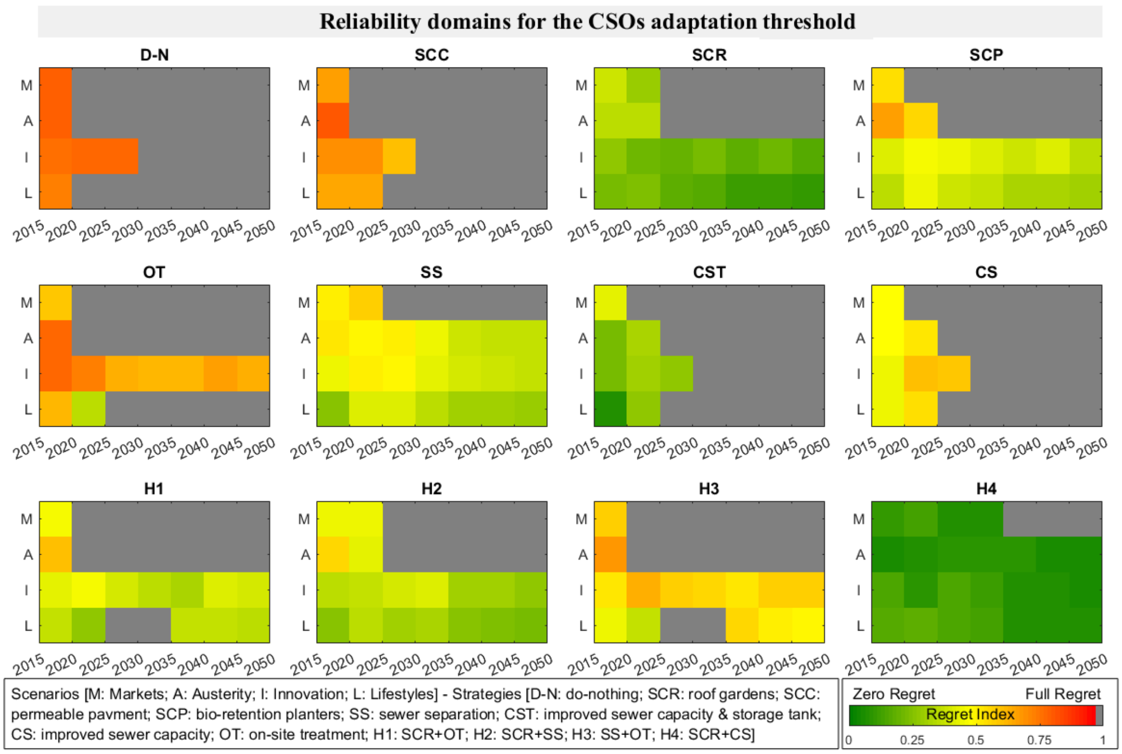

Fig. S2: Reliability domains for the CSOs adaptation threshold.

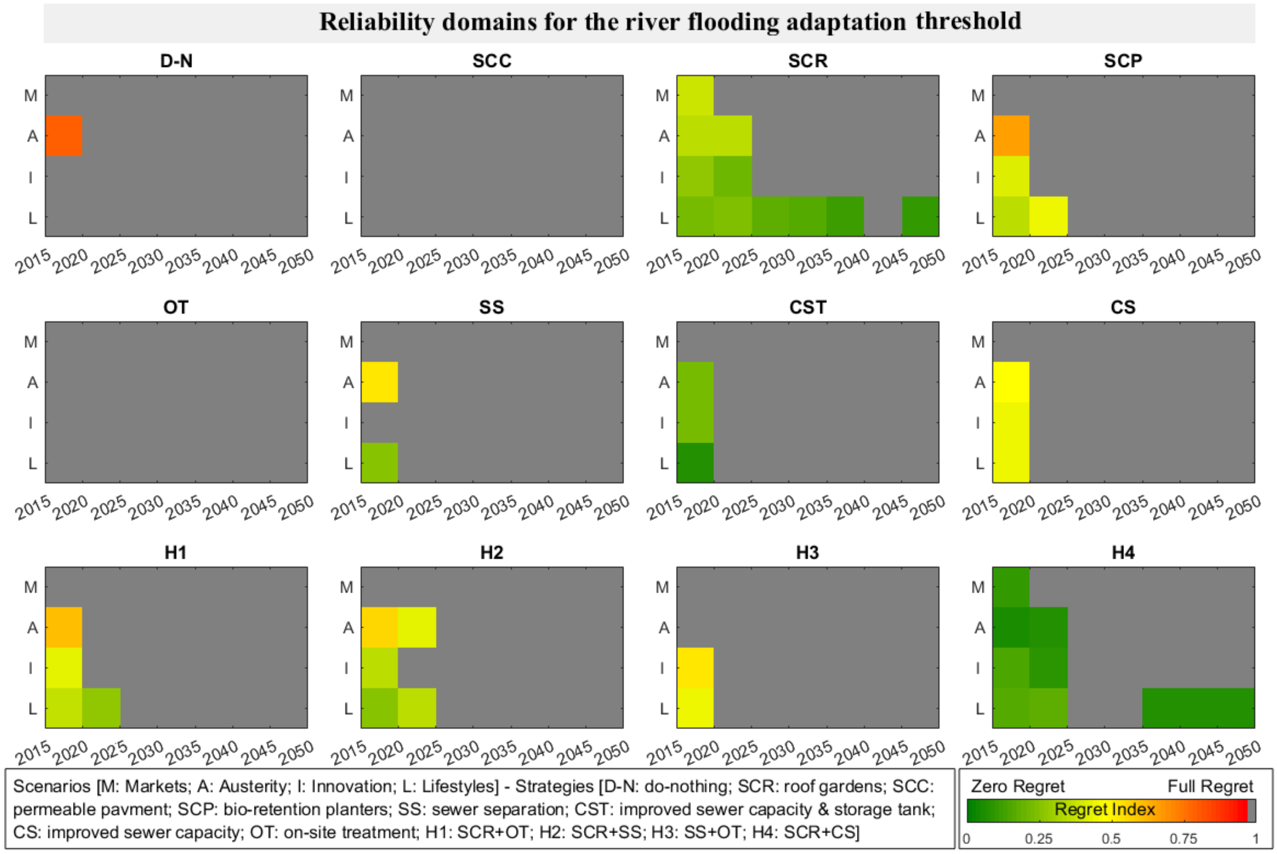

Fig. S3: Reliability domains for the river flooding adaptation threshold.

S5.2 Resilience domains for single adaptation threshold

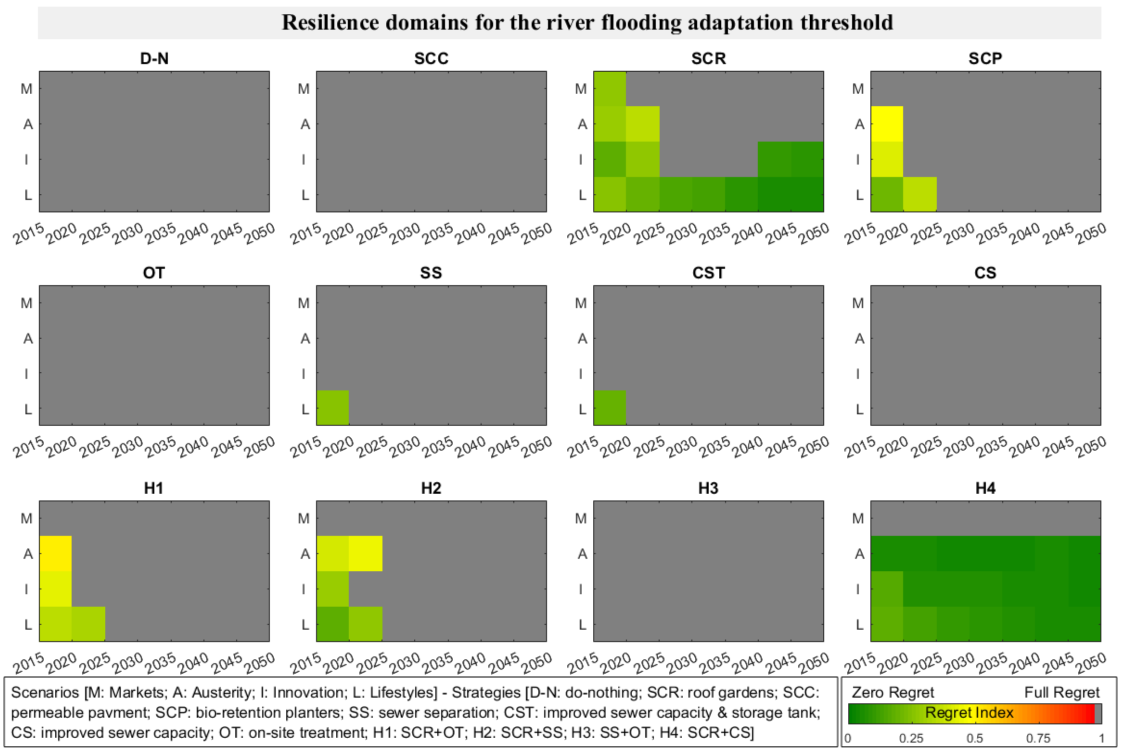

Fig. S4: Resilience domains for the river flooding adaptation threshold.

S5.3 Sustainability domains for single adaptation threshold

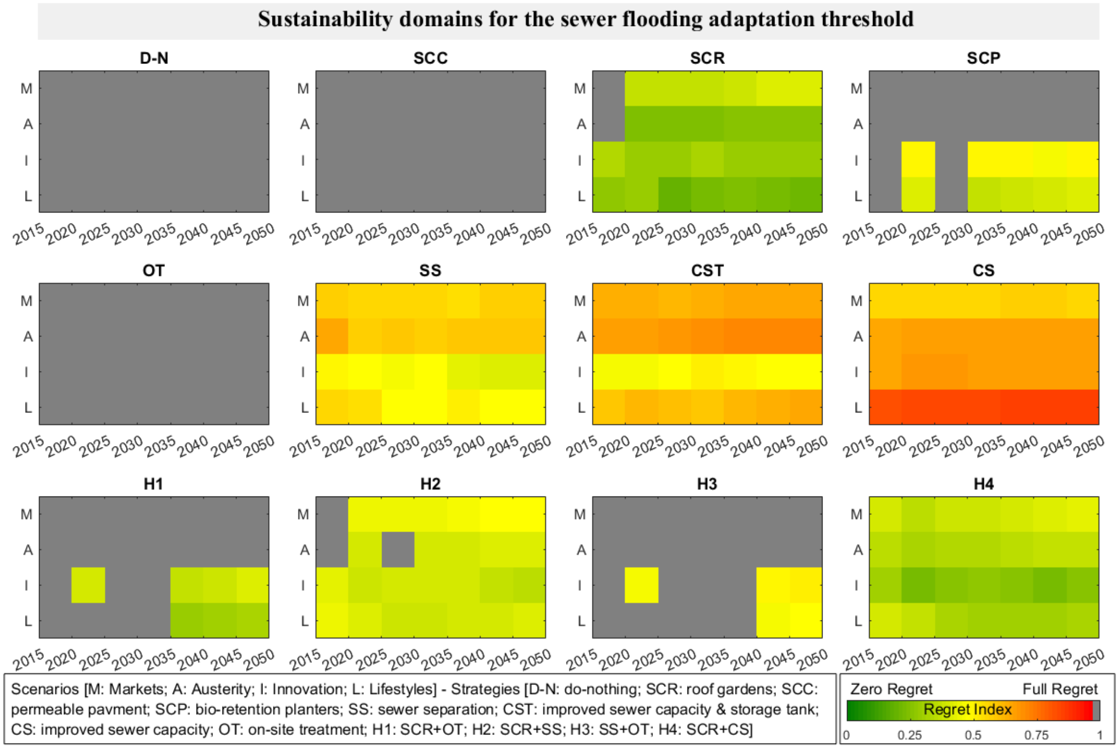

Fig. S5: Sustainability domains for the sewer flooding adaptation threshold.

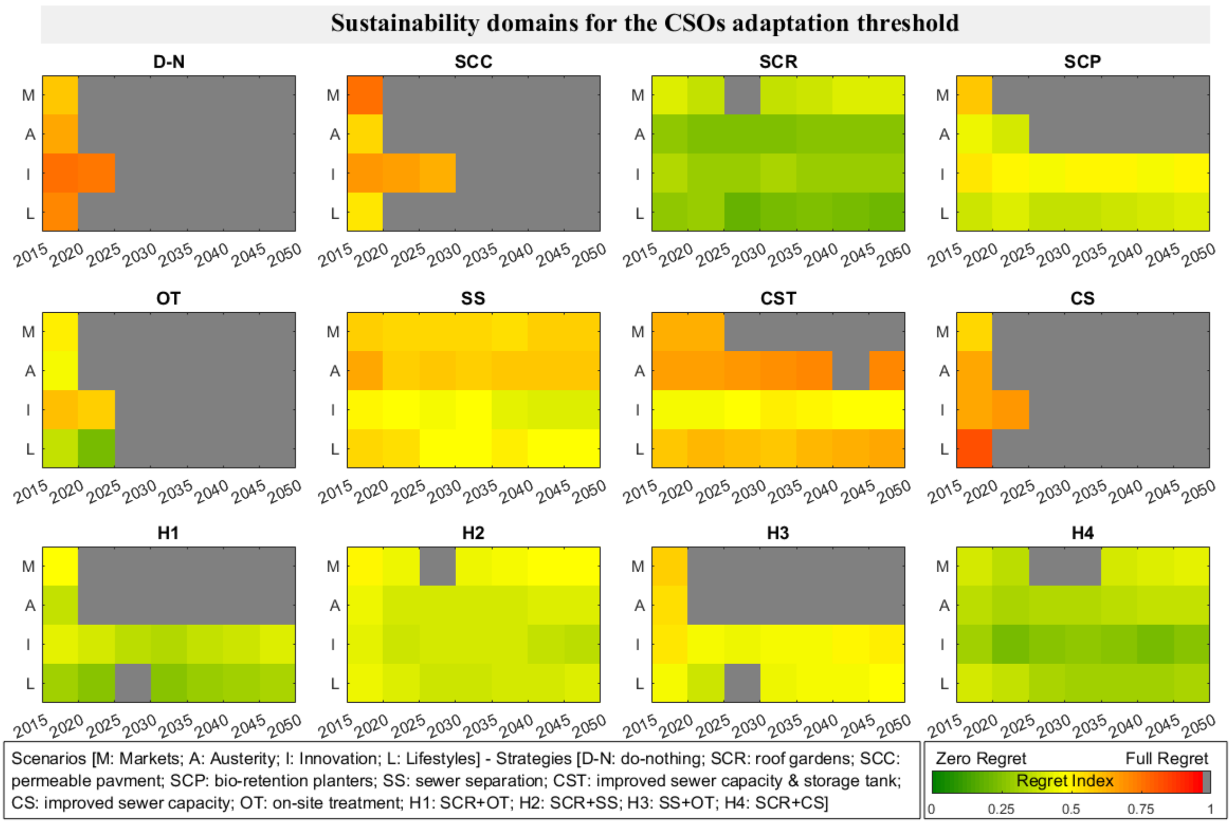

Fig. S6: Sustainability domains for the CSOs adaptation threshold.

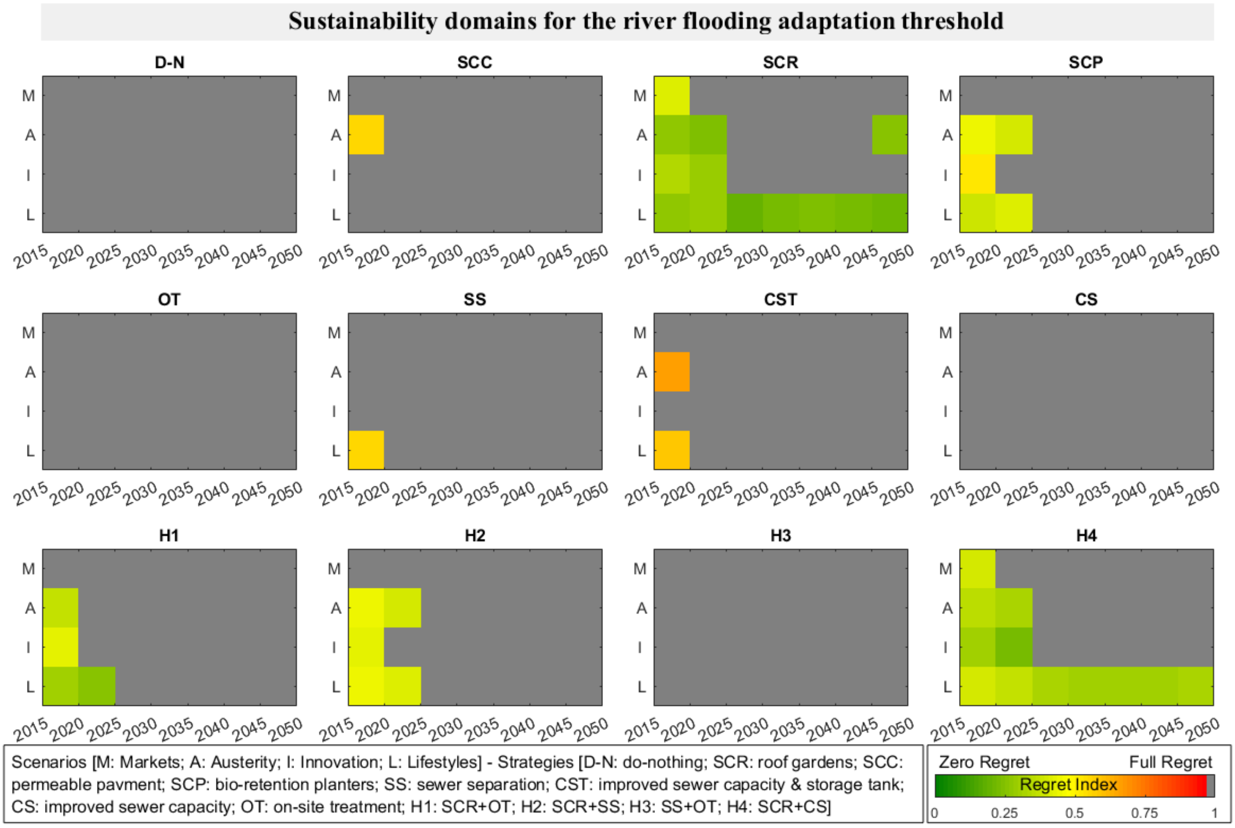

Fig. S7: Sustainability domains for the river flooding adaptation threshold.

S5.4 Reliability-Resilience domains for single adaptation threshold

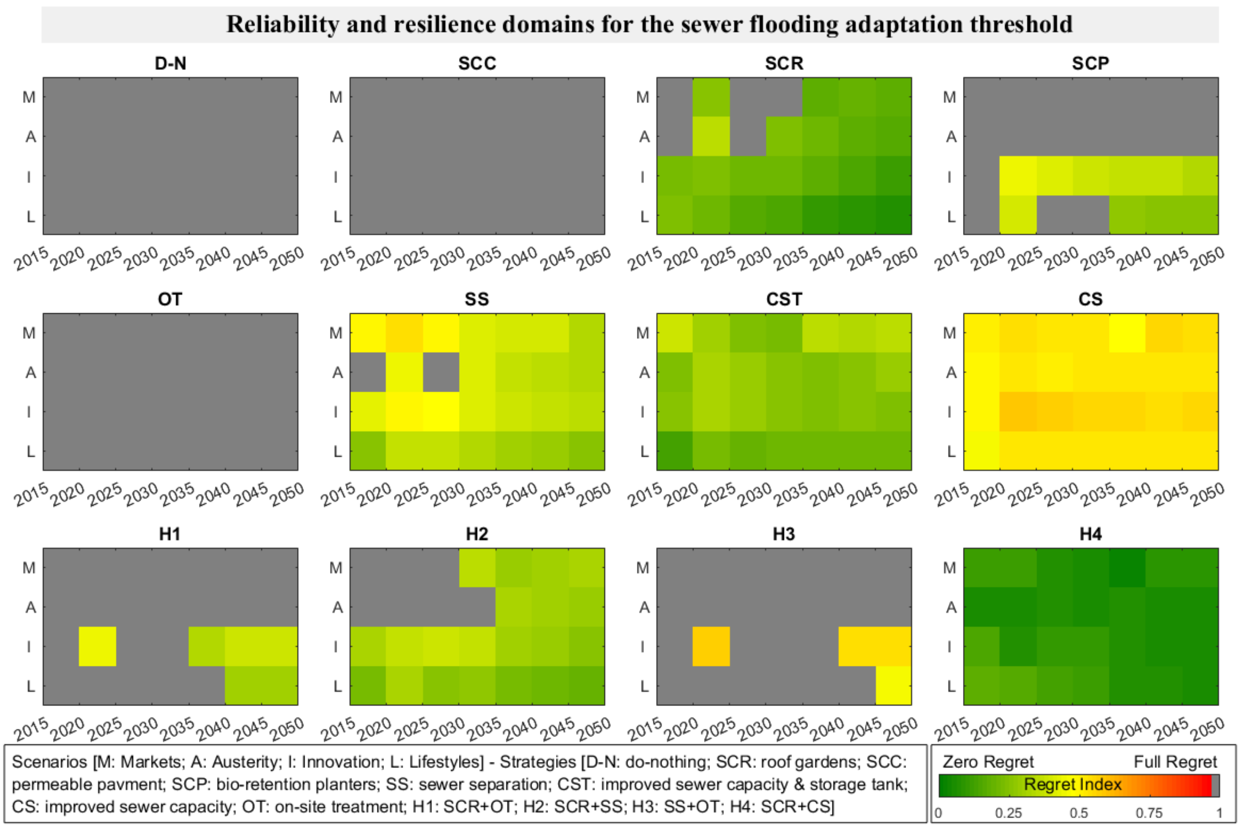

Fig. S8: Reliability and resilience domains for the sewer flooding adaptation threshold.

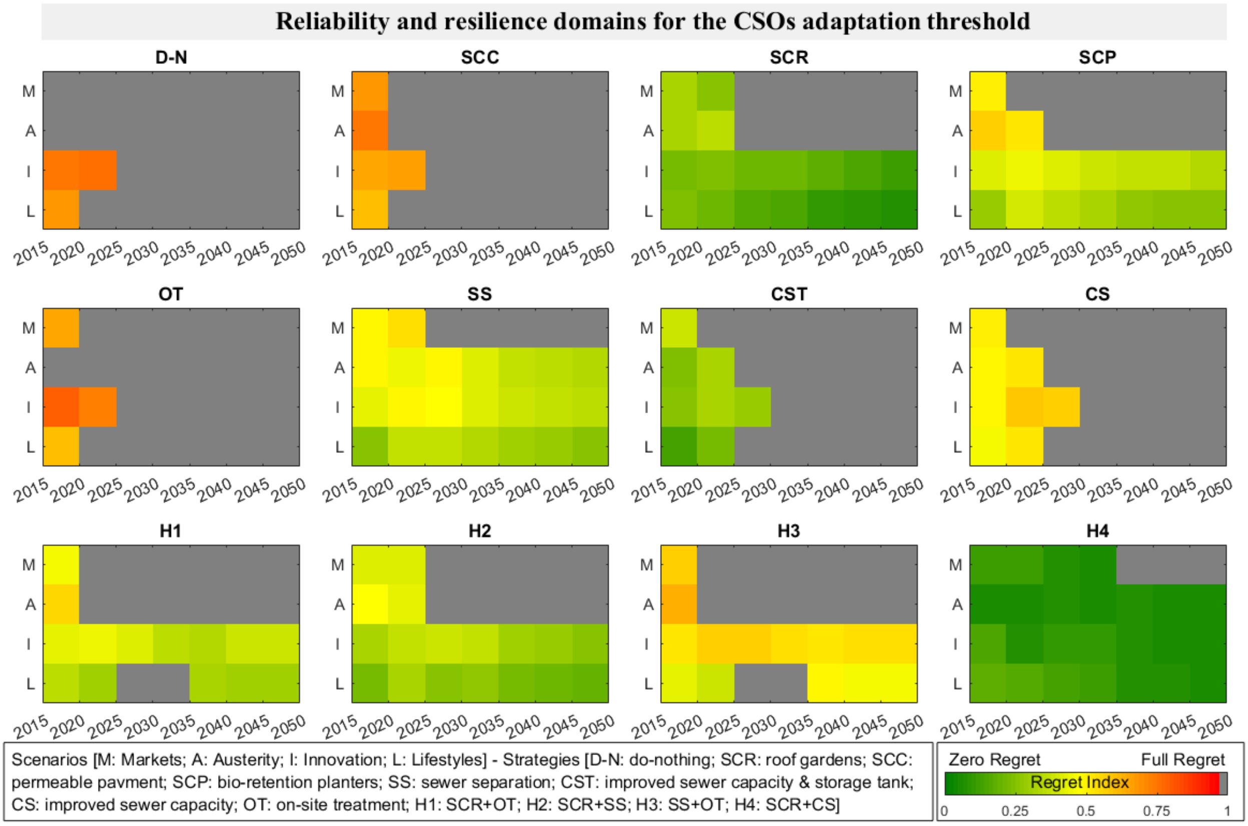

Fig. S9: Reliability and resilience domains for the CSOs adaptation threshold.

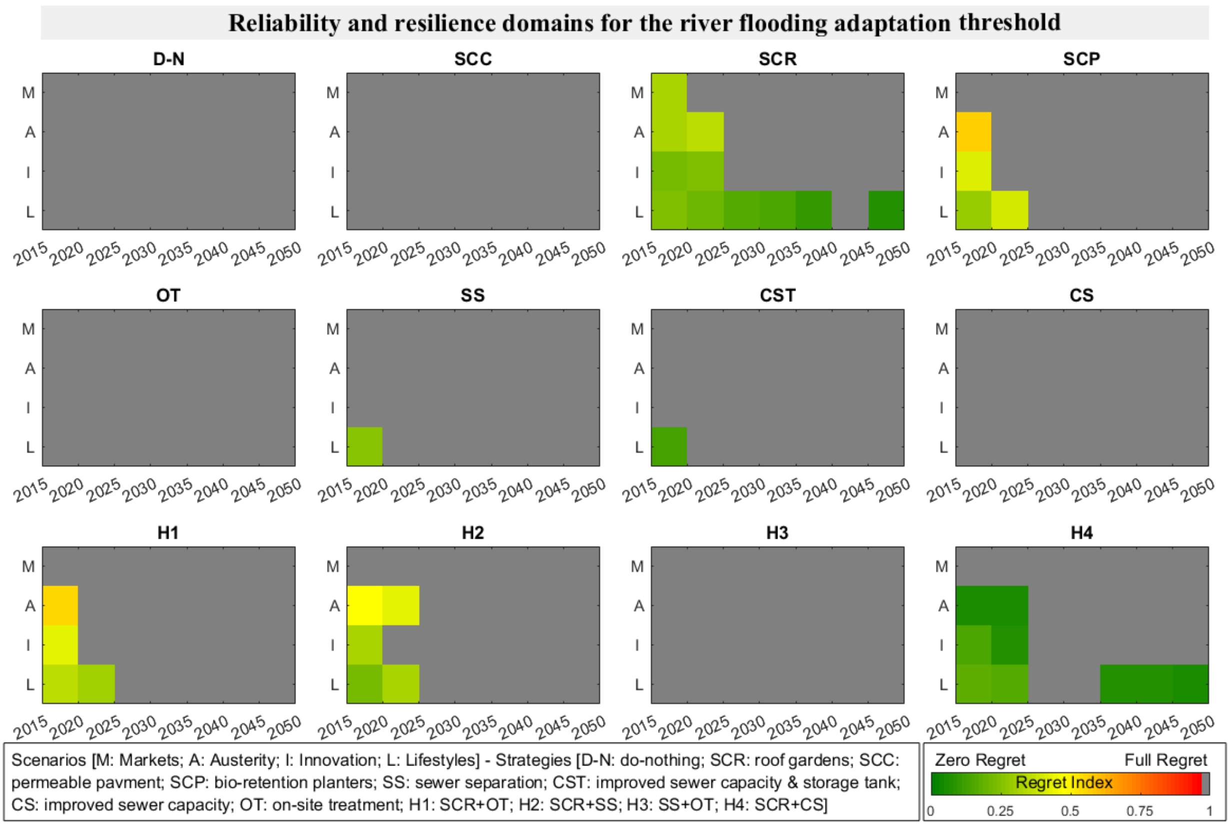

Fig. S10: Reliability and resilience domains for the river flooding adaptation threshold.

S5.5 Reliability-Sustainability domains for single adaptation threshold

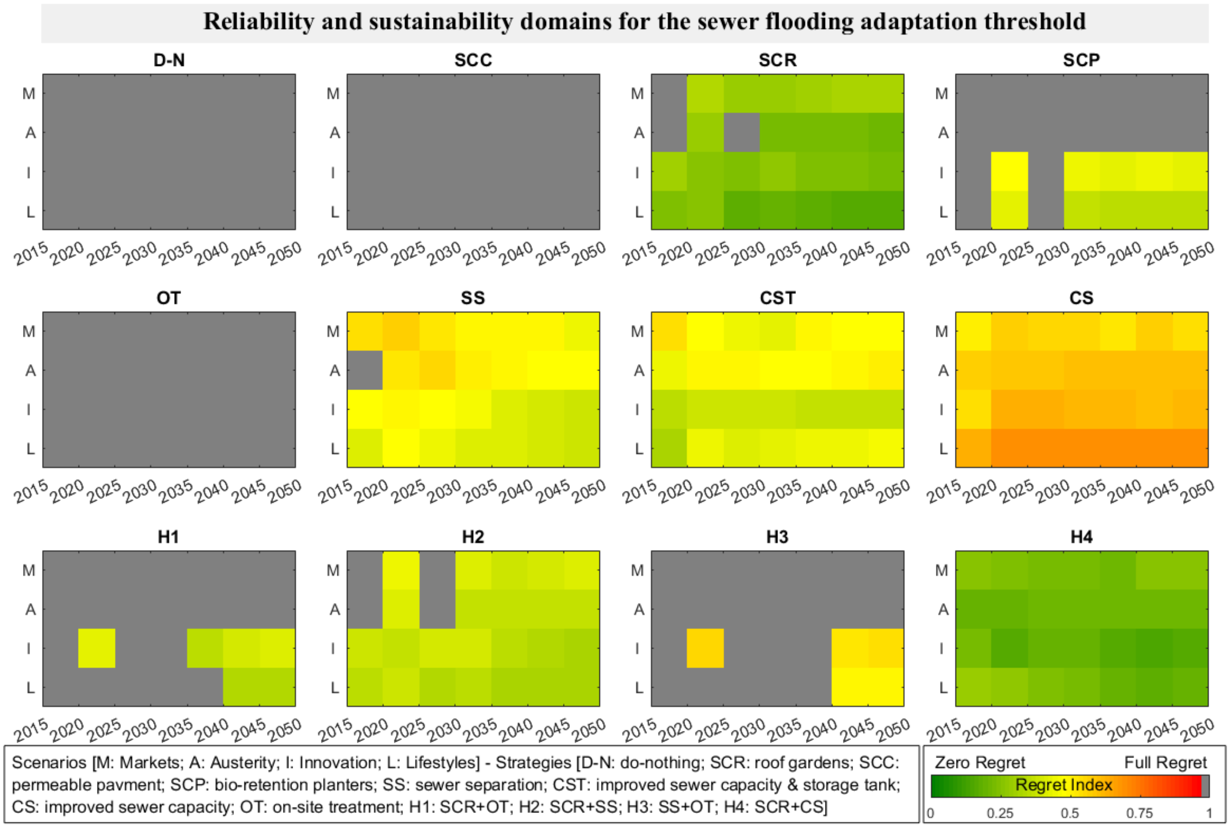

Fig. S11: Reliability and sustainability domains for the sewer flooding adaptation threshold.

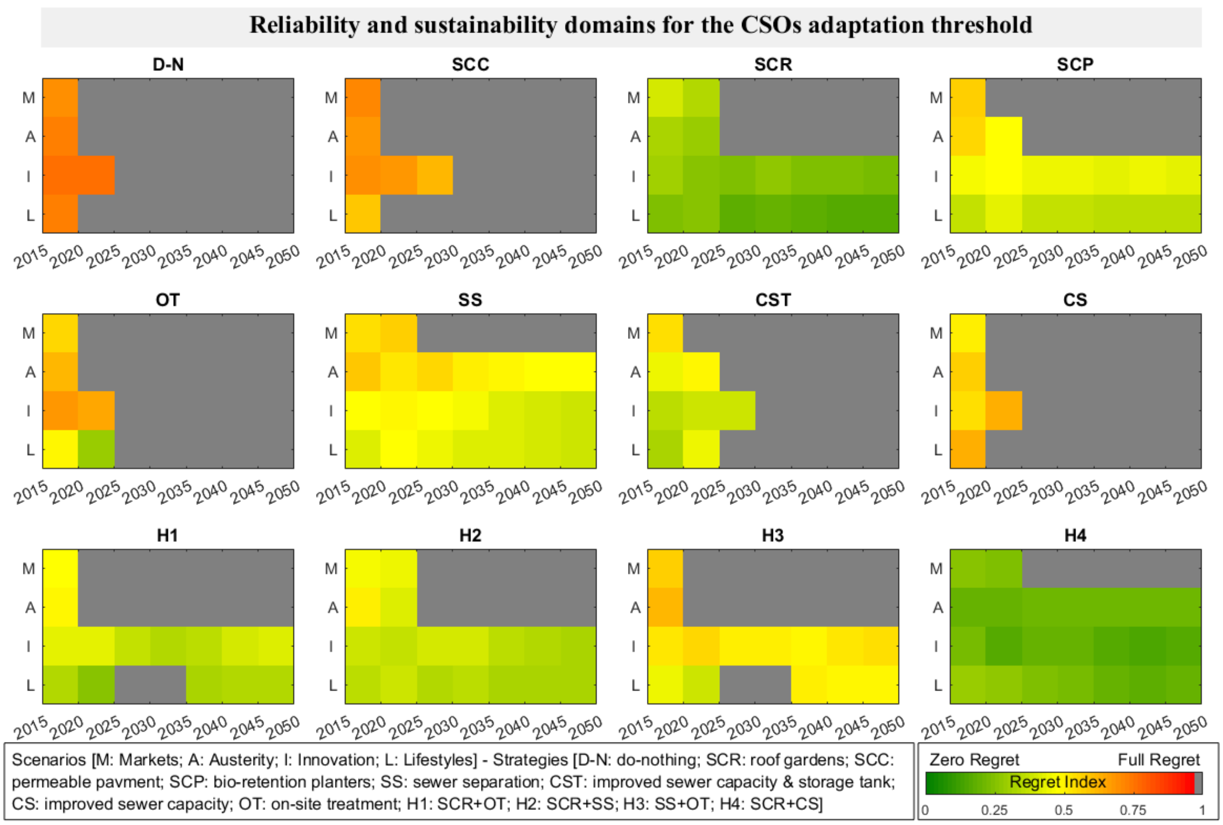

Fig. S12: Reliability and sustainability domains for the CSOs adaptation threshold.

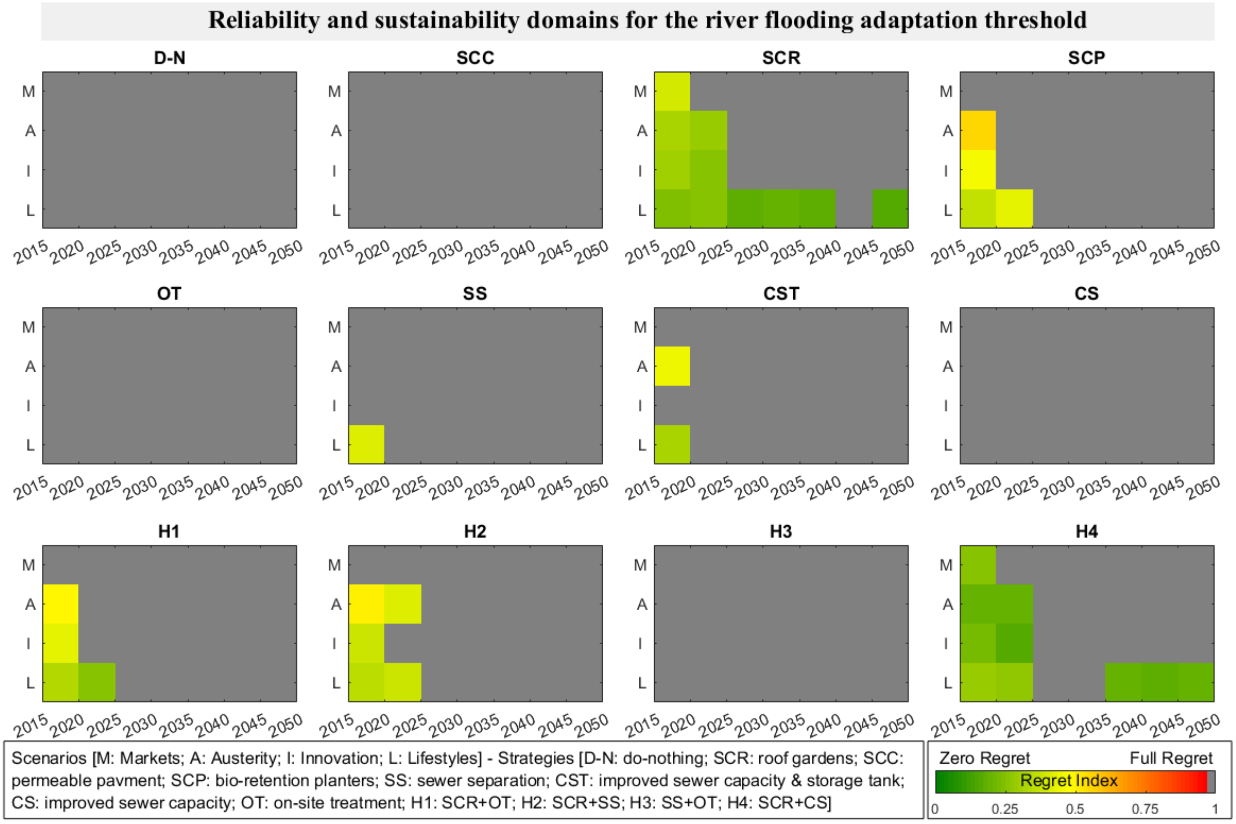

Fig. S13: Reliability and sustainability domains for the river flooding adaptation threshold.

S5.6 Resilience-Sustainability domains for single adaptation threshold

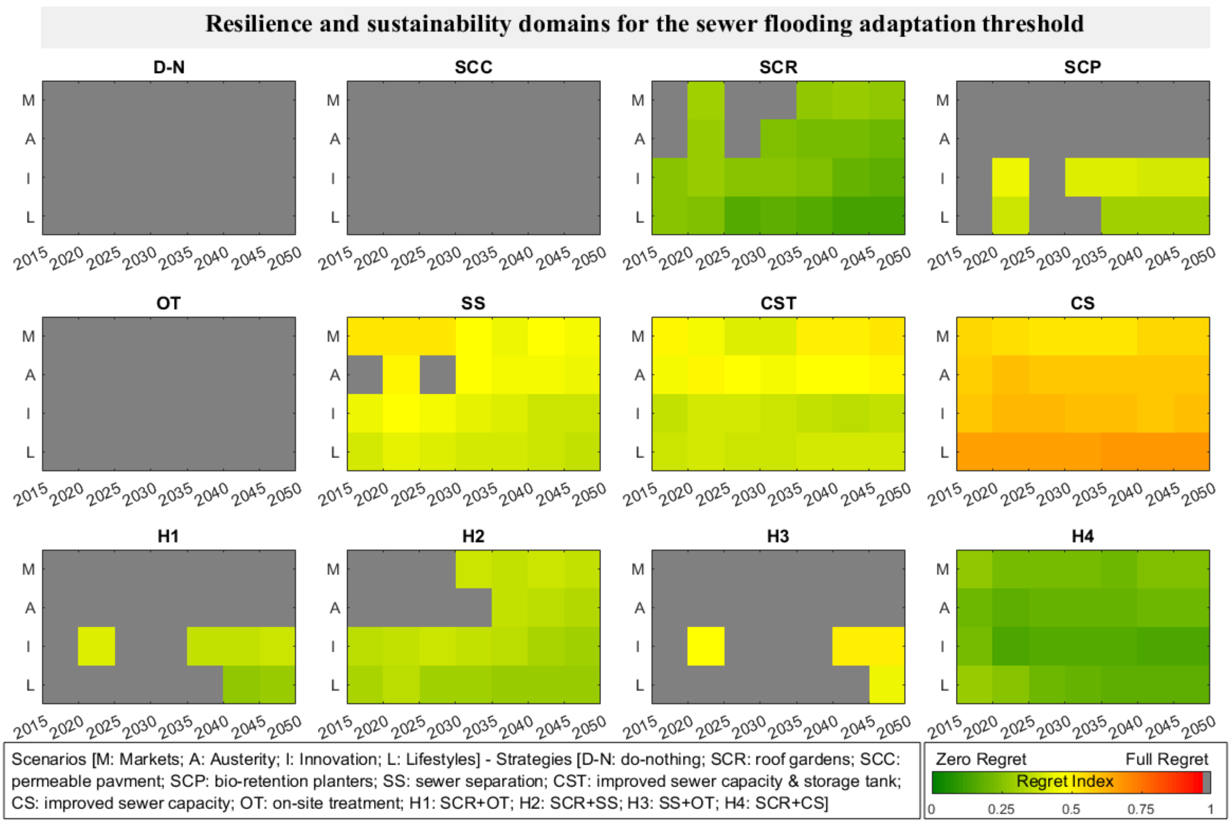

Fig. S14: Resilience and sustainability domains for the sewer flooding adaptation threshold.

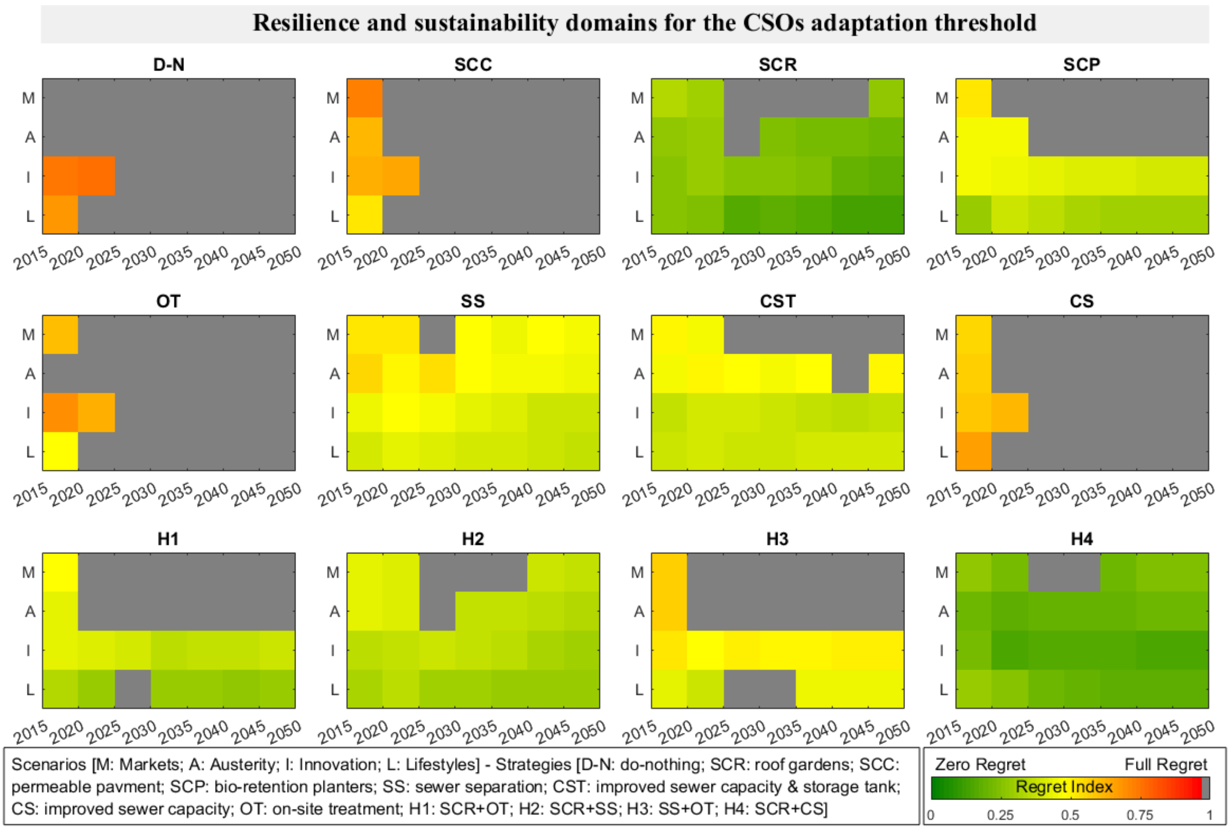

Fig. S15: Resilience and sustainability domains for the CSOs adaptation threshold.

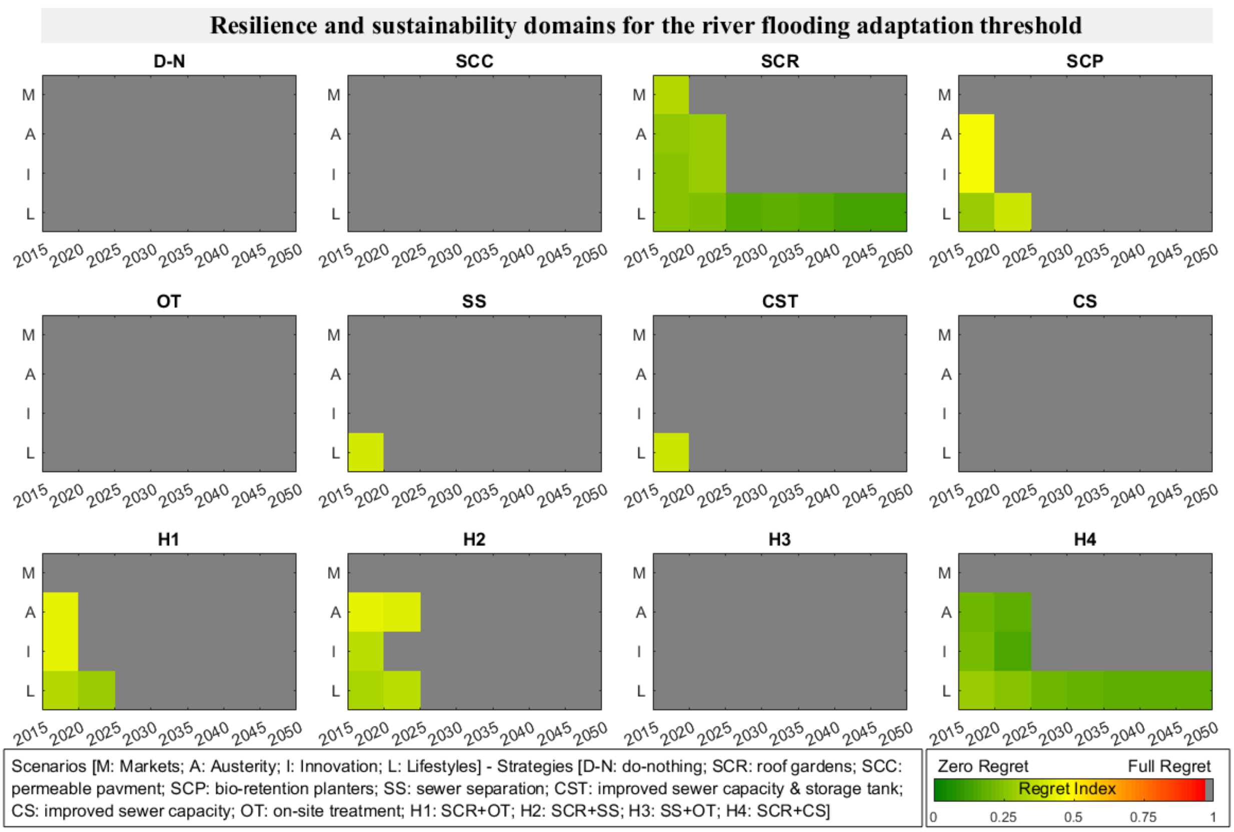

Fig. S16: Resilience and sustainability domains for the river flooding adaptation threshold.

S5.7 Reliability-Resilience-Sustainability domains for single adaptation threshold

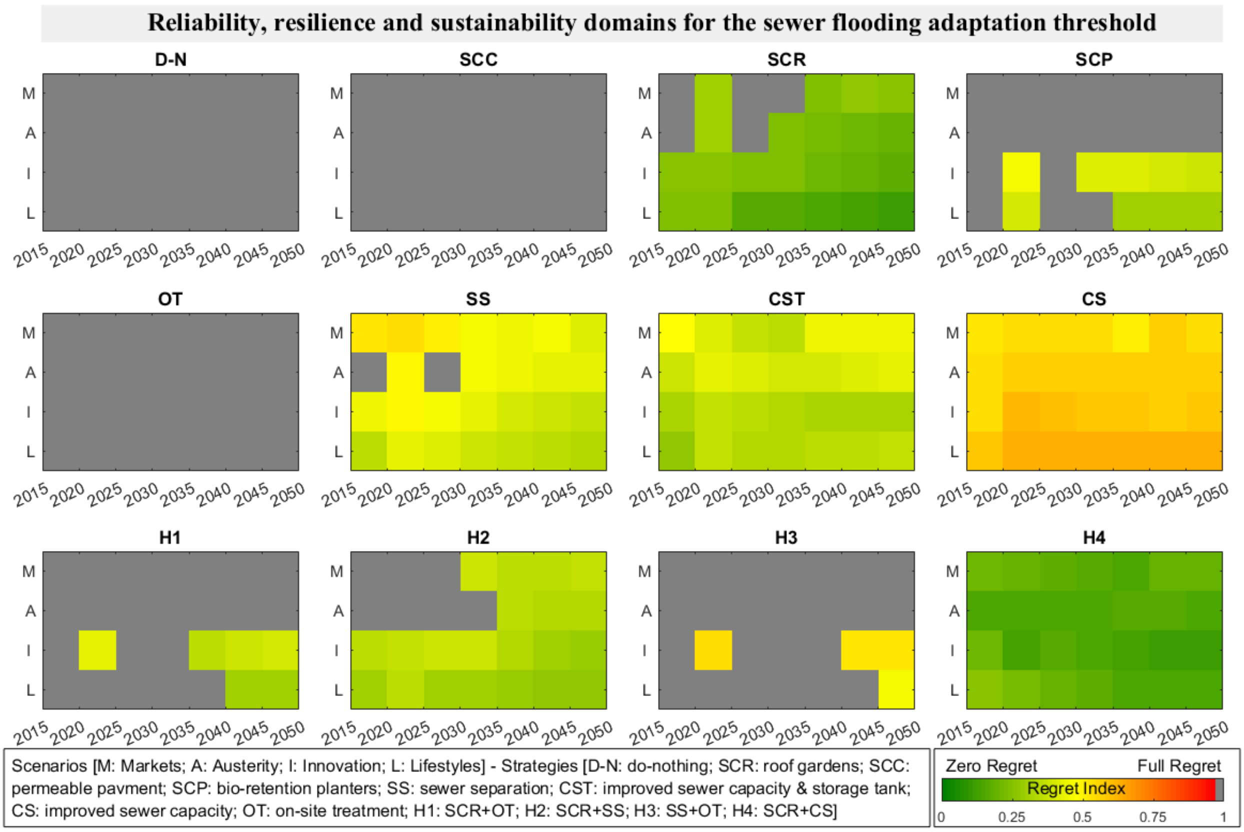

Fig. S17: Reliability, resilience and sustainability domains for the sewer flooding adaptation threshold.

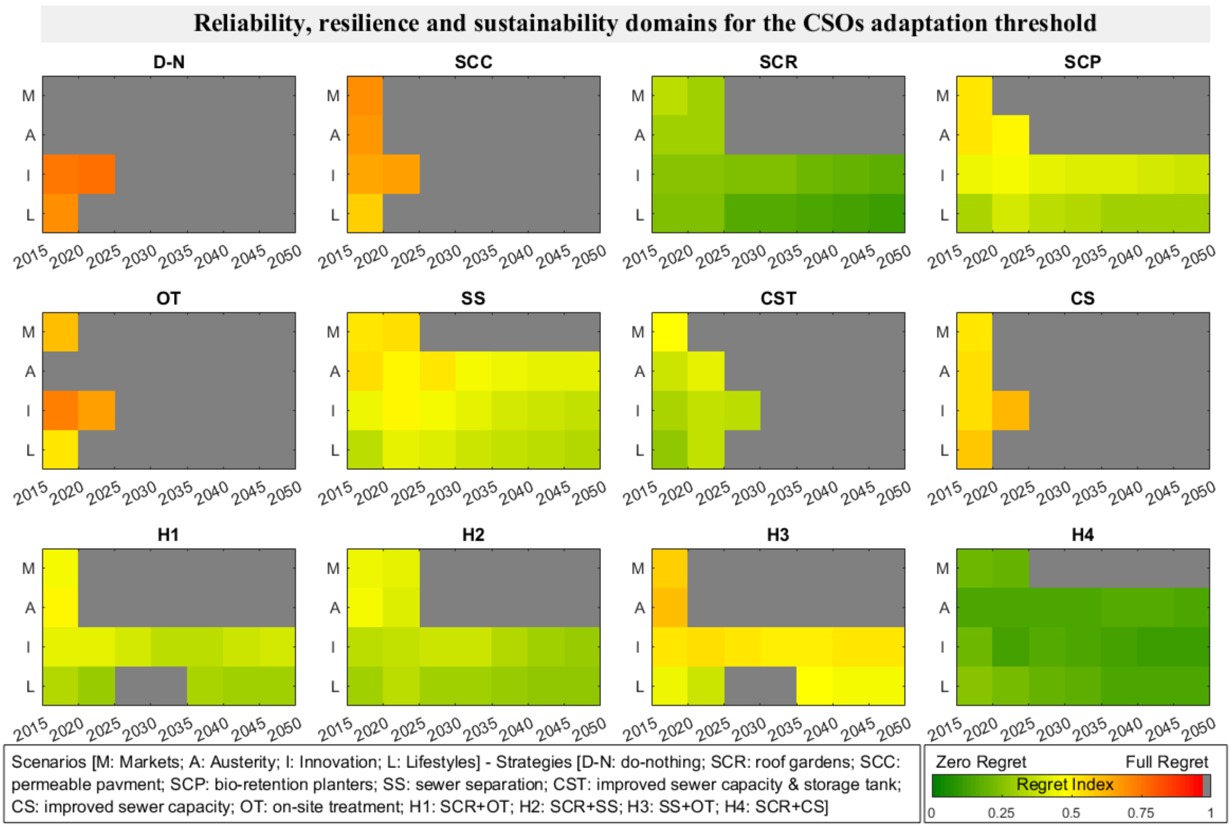

Fig. S18: Reliability, resilience and sustainability domains for the CSOs adaptation threshold.

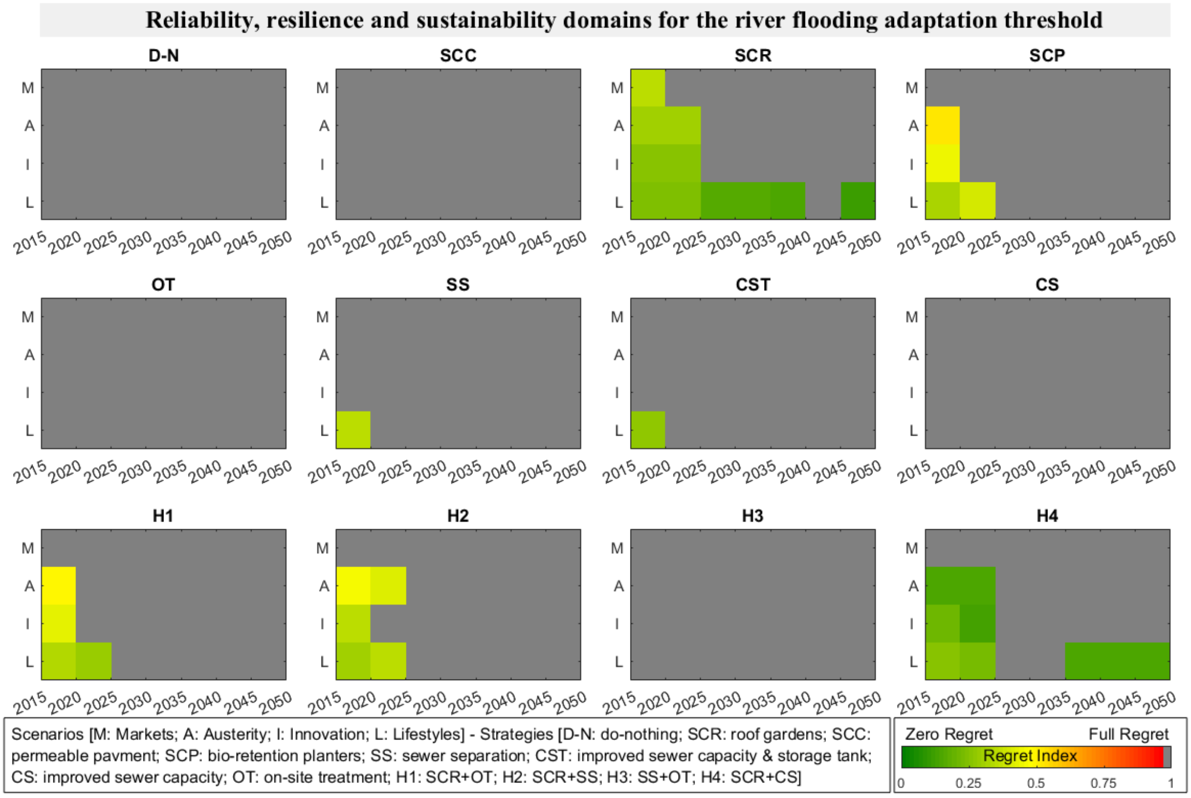

Fig. S19: Reliability, resilience and sustainability domains for the river flooding adaptation threshold.

S6. Results on different domains for multiple adaptation thresholds

S6.1 Reliability domains for multiple adaptation thresholds

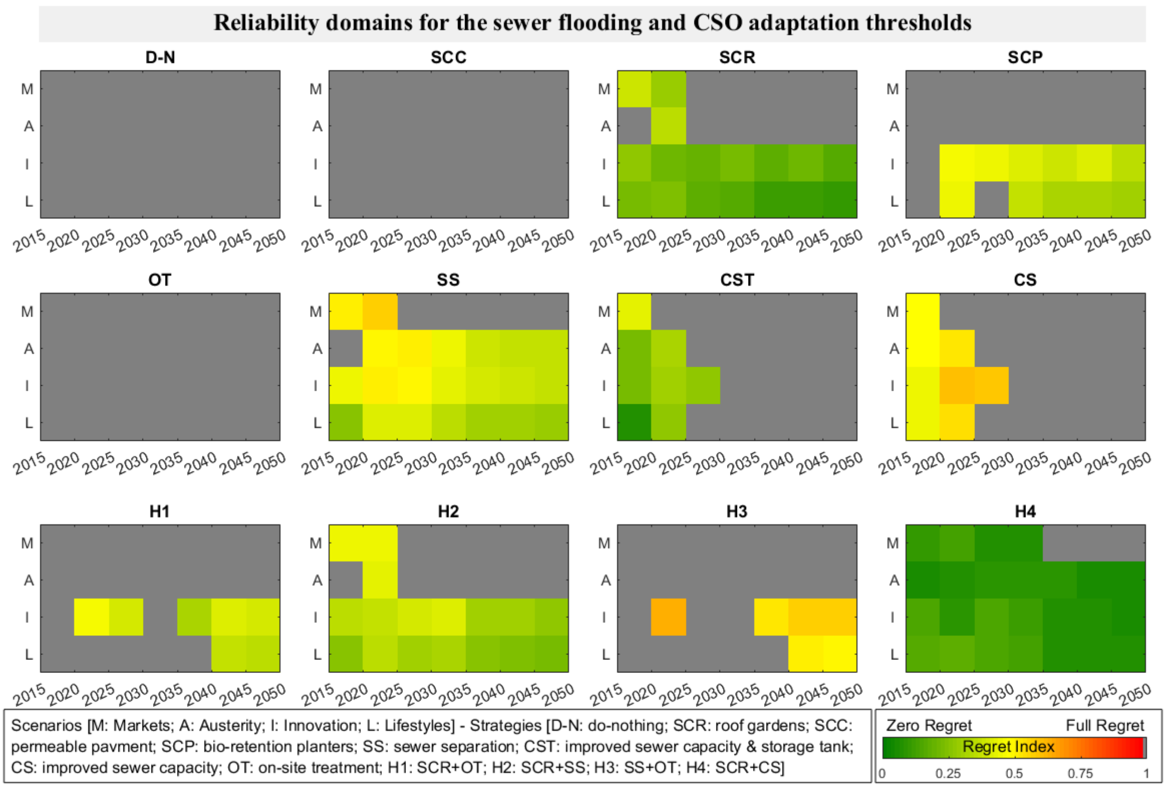

Fig. S20: Reliability domains for the sewer flooding and CSO adaptation thresholds.

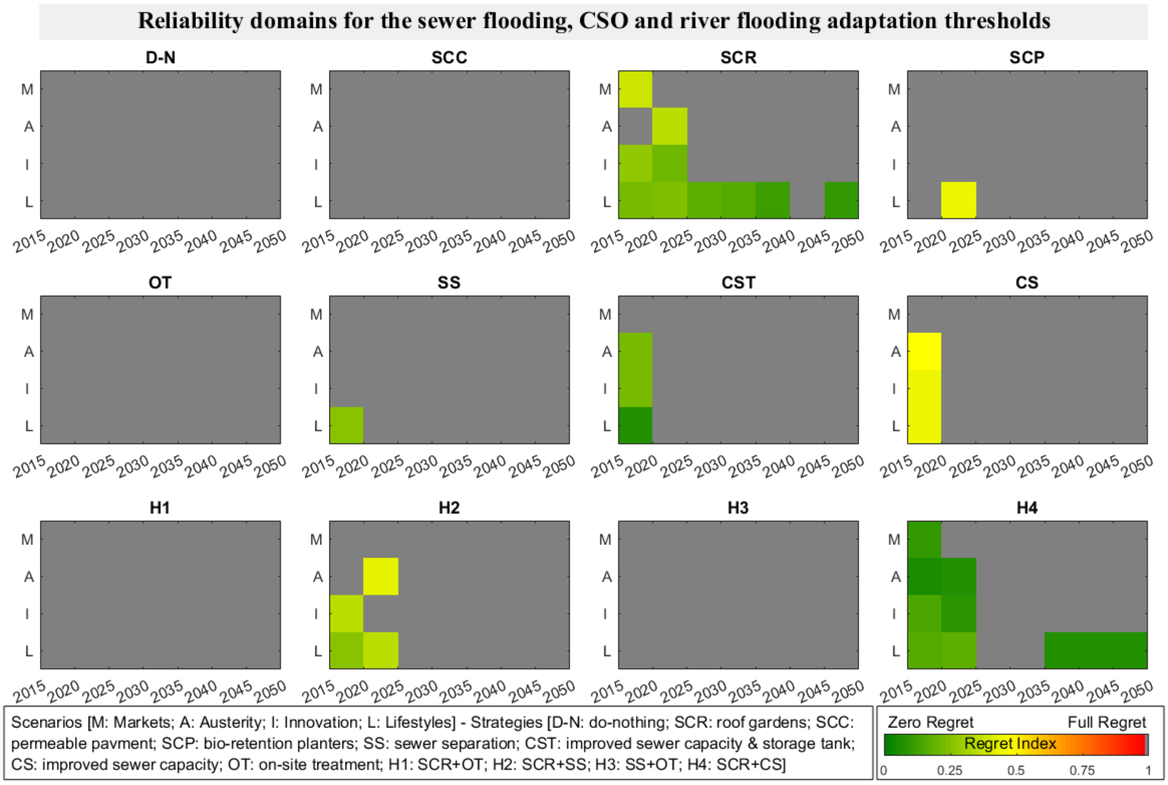

Fig. S21: Reliability domains for the sewer flooding, CSO and river flooding adaptation thresholds.

S6.2 Resilience domains for multiple adaptation thresholds

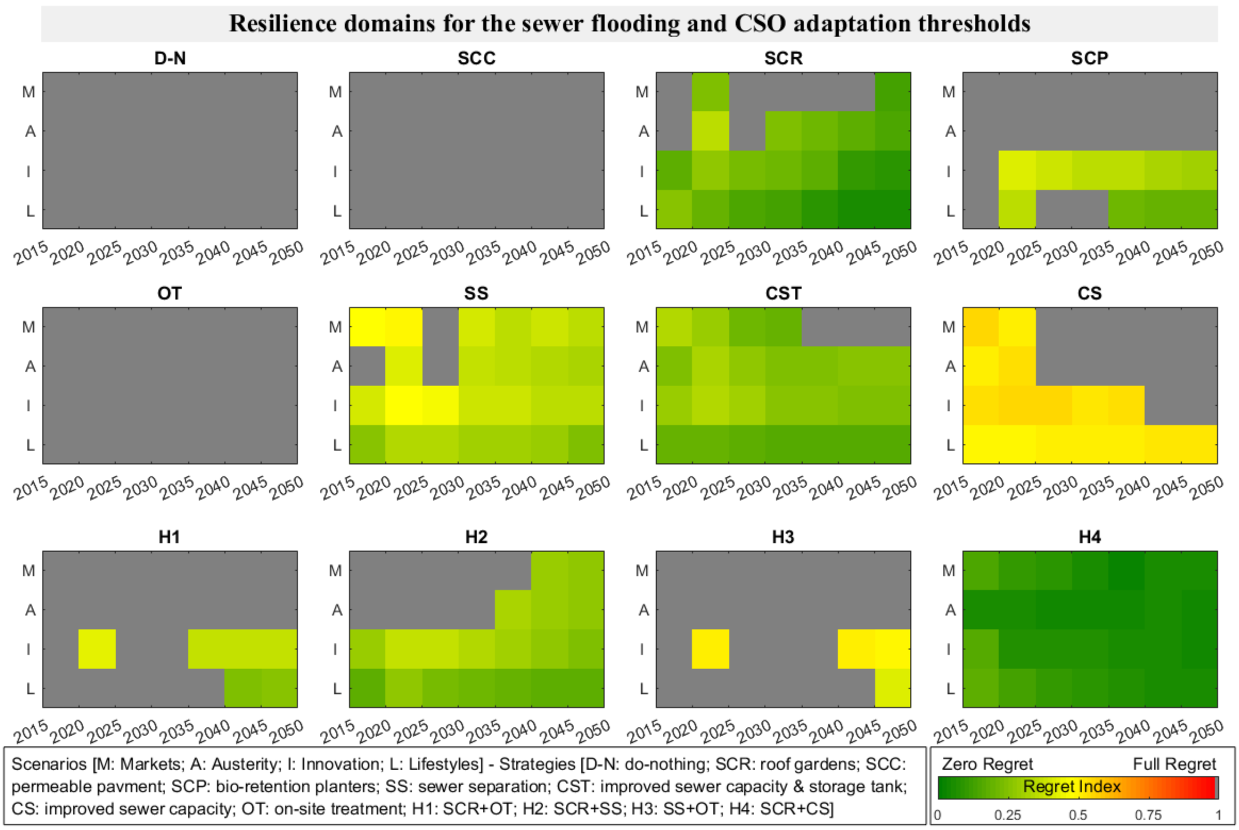

Fig. S22: Resilience domains for the sewer flooding and CSO adaptation thresholds.

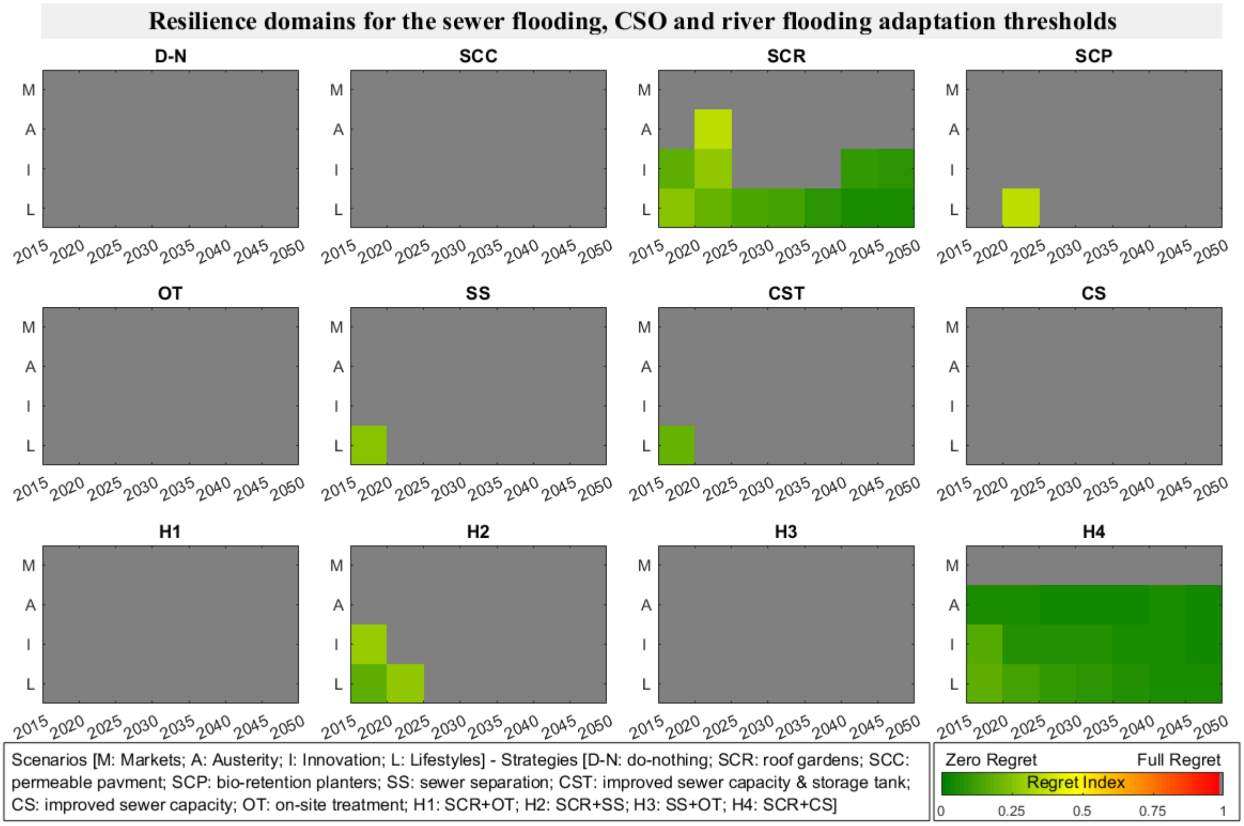

Fig. S23: Resilience domains for the sewer flooding, CSO and river flooding adaptation thresholds.

S6.3 Sustainability domains for multiple adaptation thresholds

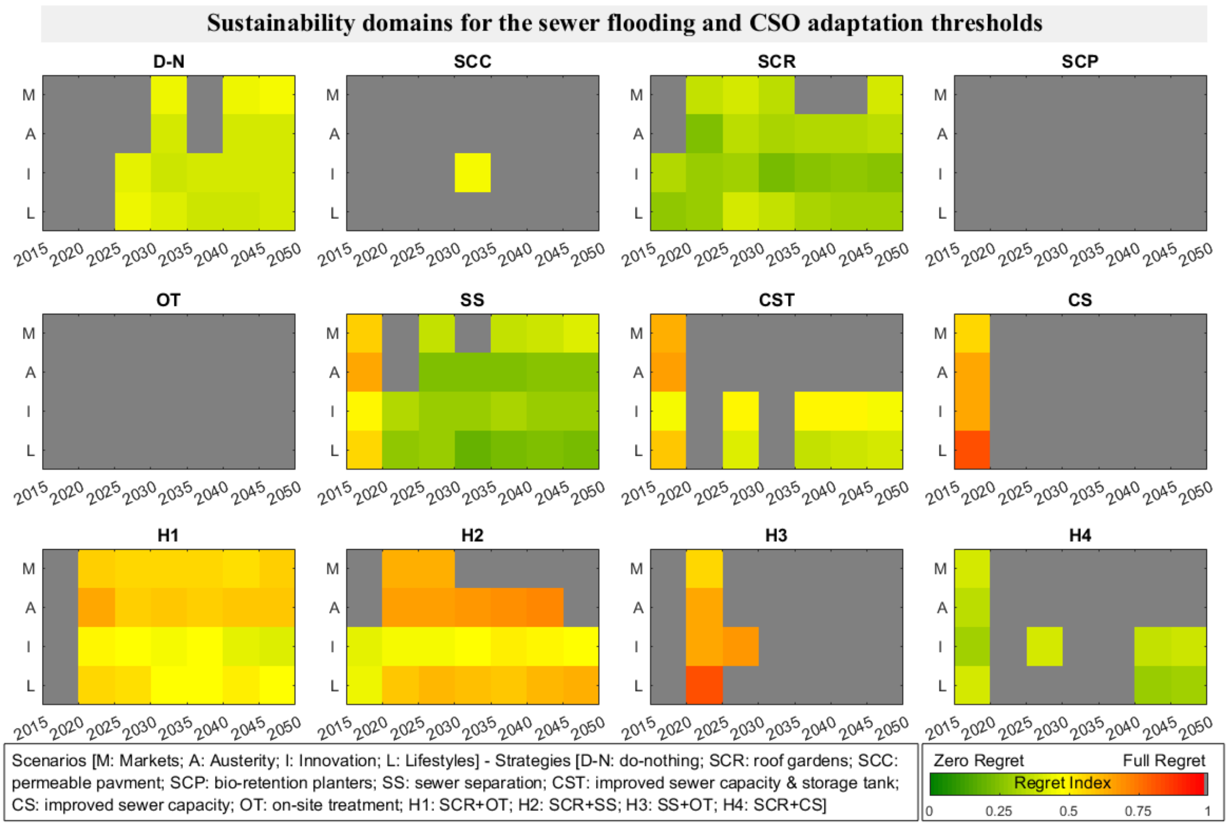

Fig. S24: Sustainability domains for the sewer flooding and CSO adaptation thresholds.

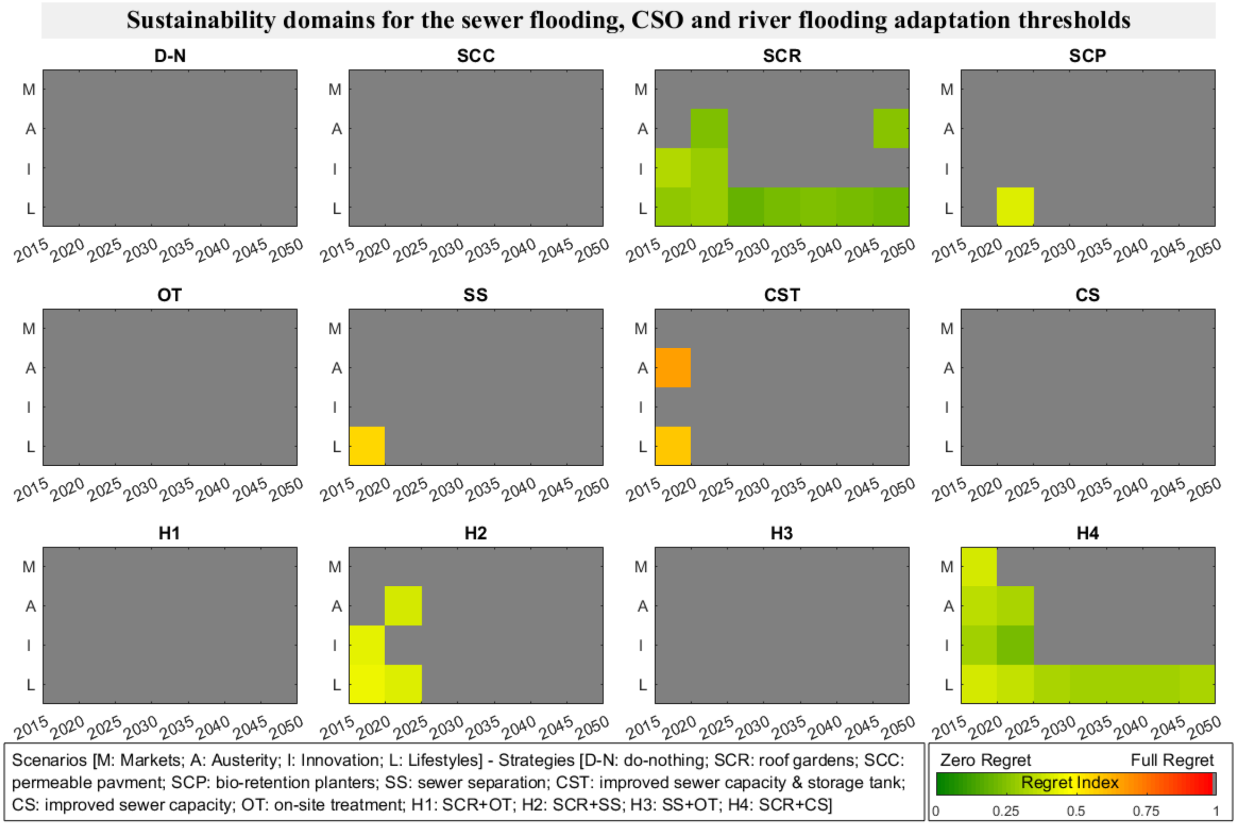

Fig. S25: Sustainability domains for the sewer flooding, CSO and river flooding adaptation thresholds.

S6.4 Reliability-Resilience domains for multiple adaptation thresholds

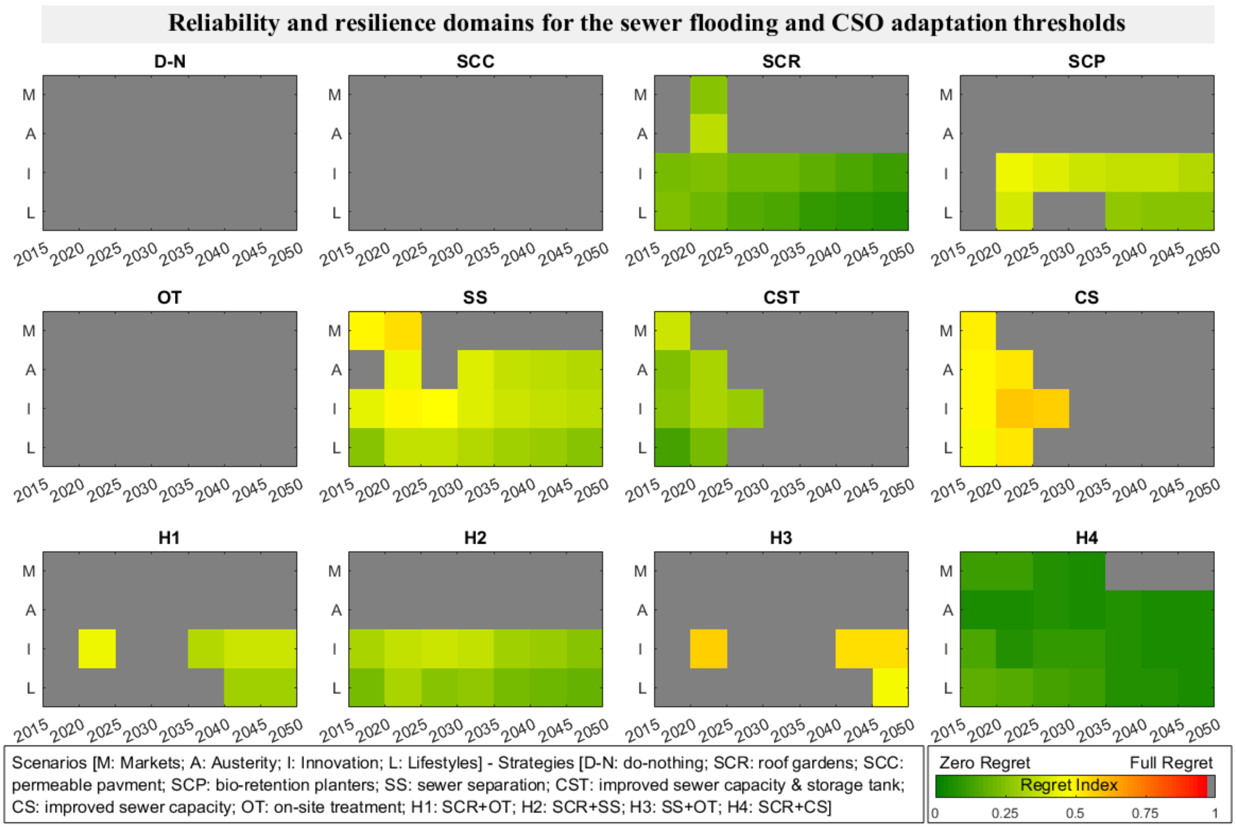

Fig. S26: Reliability and resilience domains for the sewer flooding and CSO adaptation thresholds.

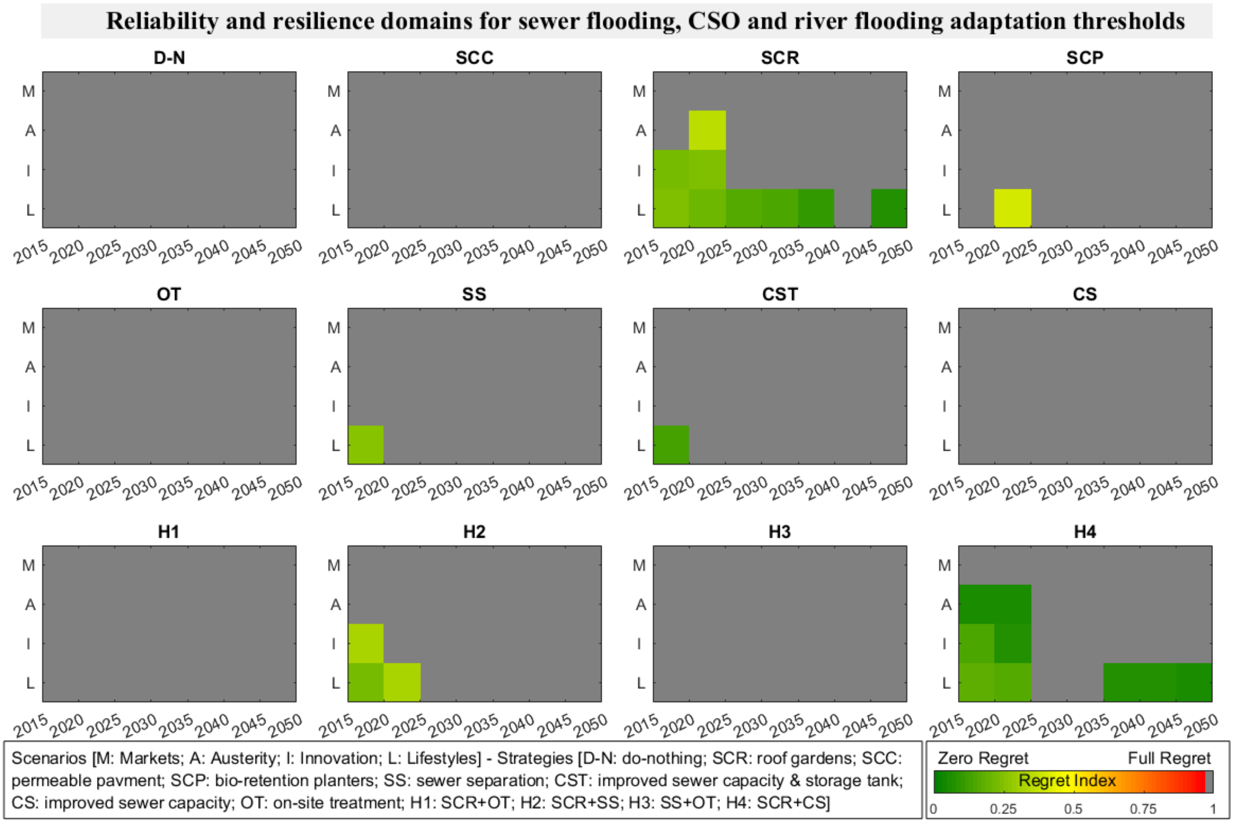

Fig. S27: Reliability and resilience domains for CSO and sewer and river flooding adaptation thresholds.

S6.5 Reliability-Sustainability domains for multiple adaptation thresholds

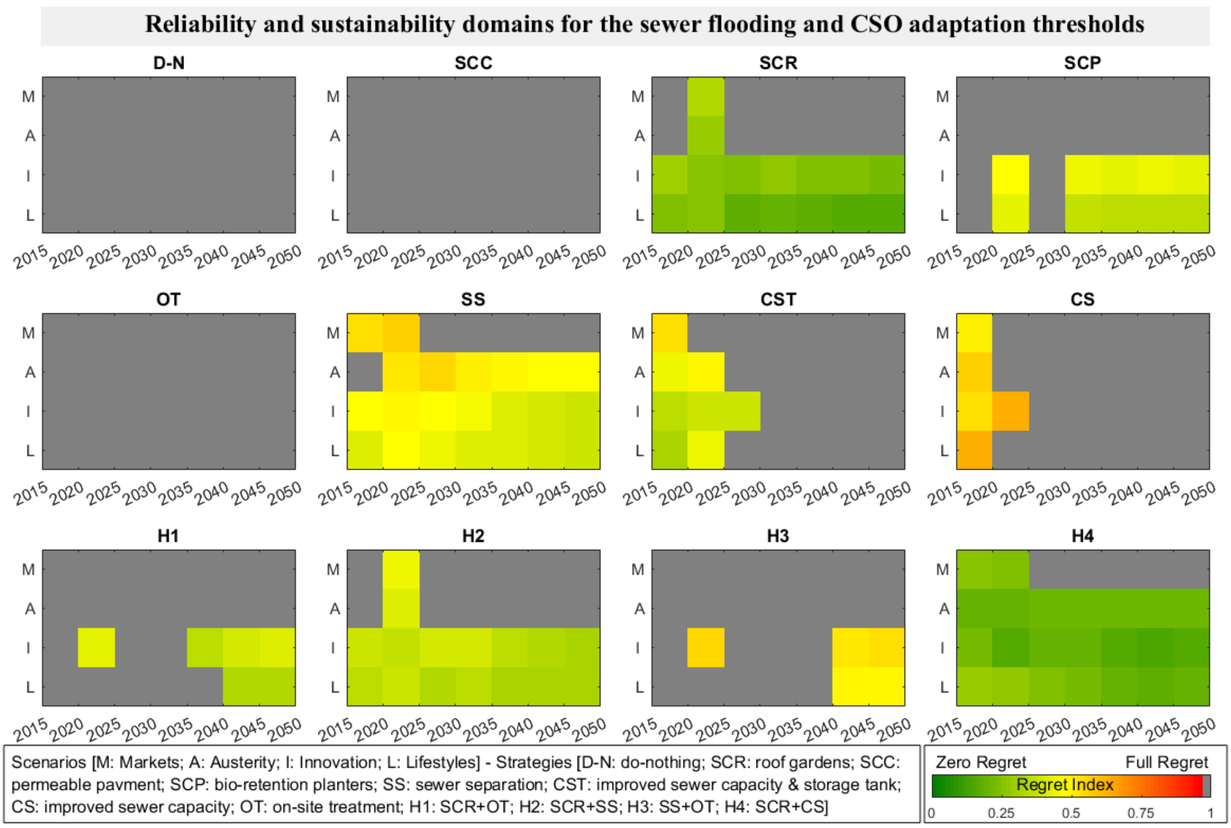

Fig. S28: Reliability and sustainability domains for the sewer flooding and CSO adaptation thresholds.

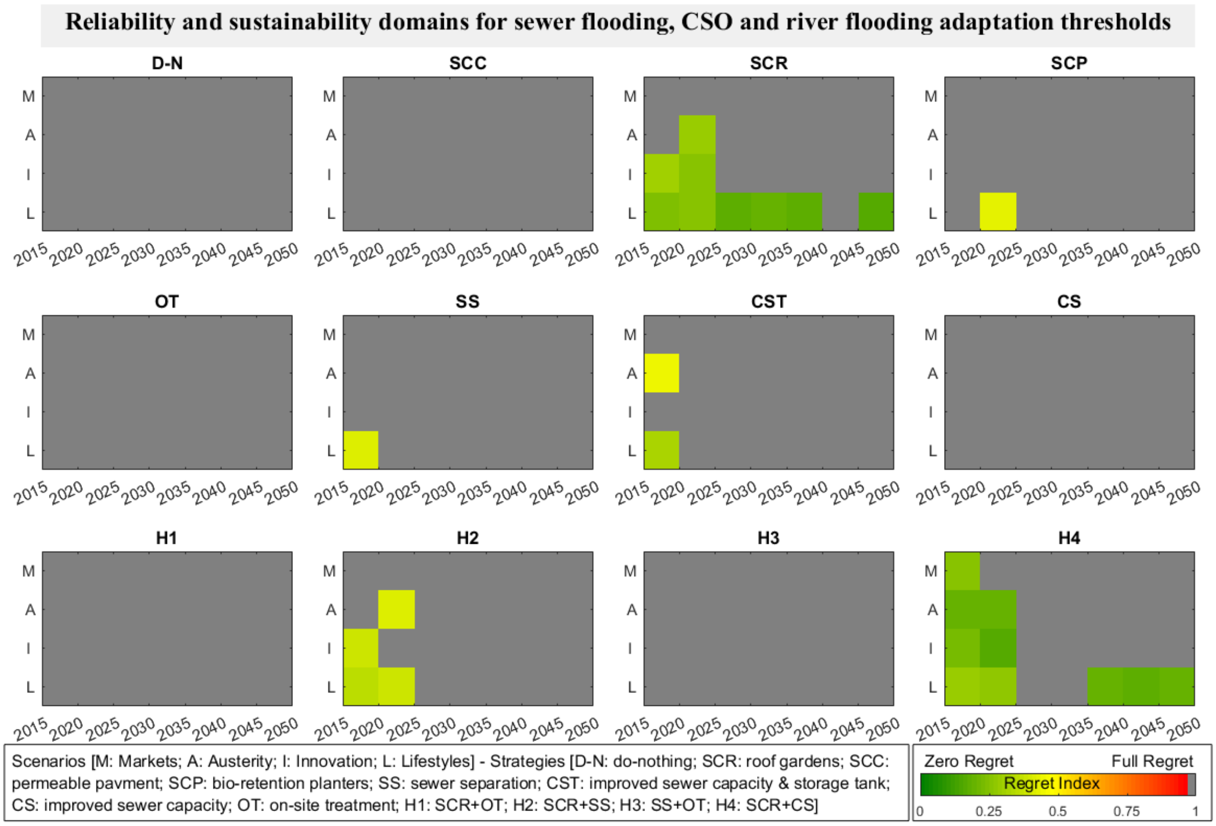

Fig. S29: Reliability and sustainability domains for sewer flooding, CSO and river flooding thresholds.

S6.6 Resilience-Sustainability domains for three adaptation thresholds

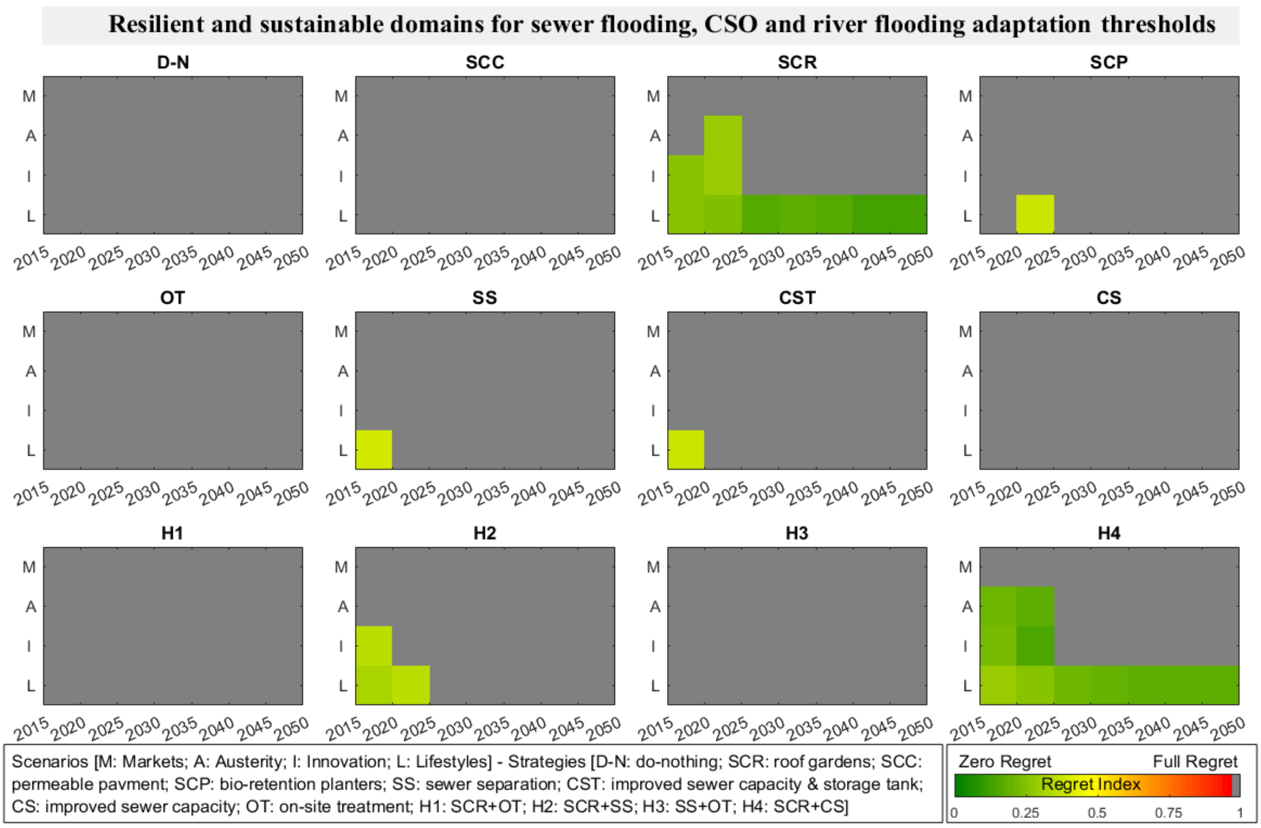

Fig. S30: Resilient and sustainable domains for sewer flooding, CSO and river flooding adaptation thresholds.

S7. Detailed results on adaptation compliancy of the strategies (evaluation of the domain size)

S7.1 Results on compliancy of the strategies with respect to multiple adaptation thresholds and multiple domains (resilience-sustainability)

Table S4: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2020

Scenarios		Markets 2020		Innovation 2020		Austerity 2020		Lifestyles 2020	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	C	NC	NC	C	C
	SCP	NC	NC	NC	NC	NC	NC	NC	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	NC	NC	C	C
	CST	C	NC	C	NC	C	NC	C	C
	CS	C	NC	C	NC	C	NC	C	NC
	H1	NC	NC	NC	NC	NC	NC	NC	NC
	H2	NC	NC	C	C	NC	NC	C	C
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	C	NC	C	C	C	C	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S5: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2025

Scenarios		Markets 2025		Innovation 2025		Austerity 2025		Lifestyles 2025	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	C	NC	C	C	C	C	C	C
	SCP	NC	NC	C	NC	NC	NC	C	C
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	C	NC	C	NC
	CST	C	NC	C	NC	C	NC	C	NC
	CS	NC	NC	C	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	C
	H3	NC	NC	C	NC	NC	NC	NC	NC
	H4	C	NC	C	C	C	C	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S6: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2030

Scenarios		Markets 2030		Innovation 2030		Austerity 2030		Lifestyles 2030	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	NC	NC	C	C
	SCP	NC	NC	NC	NC	NC	NC	NC	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	NC	NC	C	NC	NC	NC	C	NC
	CST	NC	NC	C	NC	C	NC	C	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	NC	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	NC	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S7: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2035

Scenarios		Markets 2035		Innovation 2035		Austerity 2035		Lifestyles 2035	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	C	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	NC	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	C	NC	C	NC
	CST	NC	NC	C	NC	C	NC	C	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	NC	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	NC	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S8: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2040

Scenarios		Markets 2040		Innovation 2040		Austerity 2040		Lifestyles 2040	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	C	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	C	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	C	NC	C	NC
	CST	NC	NC	C	NC	C	NC	C	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	C	NC	C	NC
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	C	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S9: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2045

Scenarios		Markets 2045		Innovation 2045		Austerity 2045		Lifestyles 2045	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	C	NC	C	NC	C	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	C	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	C	NC	C	NC
	CST	NC	NC	C	NC	C	NC	C	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	C	NC
	H2	C	NC	C	NC	C	NC	C	NC
	H3	NC	NC	C	NC	NC	NC	C	NC
	H4	C	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S10: Compliancy of the strategies with respect to the domains of resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2050

Scenarios		Markets 2050		Innovation 2050		Austerity 2050		Lifestyles 2050	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	C	NC	C	NC	C	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	C	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	C	NC	C	NC
	CST	NC	NC	C	NC	C	NC	C	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	C	NC
	H2	C	NC	C	NC	C	NC	C	NC
	H3	NC	NC	C	NC	NC	NC	C	NC
	H4	C	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

S7.2 Results on compliancy of the strategies with respect to multiple adaptation thresholds and multiple domains (reliability-resilience-sustainability)

Table S11: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2020

Scenarios		Markets 2020		Innovation 2020		Austerity 2020		Lifestyles 2020	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	C	NC	NC	C	C
	SCP	NC	NC	NC	NC	NC	NC	NC	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	NC	NC	C	C
	CST	C	NC	C	NC	C	NC	C	C
	CS	C	NC	C	NC	C	NC	C	NC
	H1	NC	NC	NC	NC	NC	NC	NC	NC
	H2	NC	NC	C	C	NC	NC	C	C
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	C	NC	C	C	C	C	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S12: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2025

Scenarios		Markets 2025		Innovation 2025		Austerity 2025		Lifestyles 2025	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	C	NC	C	C	C	C	C	C
	SCP	NC	NC	C	NC	NC	NC	C	C
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	C	NC	C	NC	C	NC	C	NC
	CST	NC	NC	C	NC	C	NC	C	NC
	CS	NC	NC	C	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	C
	H3	NC	NC	C	NC	NC	NC	NC	NC
	H4	C	NC	C	C	C	C	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S13: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2030

Scenarios		Markets 2030		Innovation 2030		Austerity 2030		Lifestyles 2030	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	NC	NC	C	C
	SCP	NC	NC	NC	NC	NC	NC	NC	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	NC	NC	C	NC	NC	NC	C	NC
	CST	NC	NC	C	NC	NC	NC	NC	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	NC	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	NC	NC	C	NC	C	NC	C	NC

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S14: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2035

Scenarios		Markets 2035		Innovation 2035		Austerity 2035		Lifestyles 2035	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	NC	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	NC	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	NC	NC	C	NC	C	NC	C	NC
	CST	NC	NC	NC	NC	NC	NC	NC	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	NC	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	NC	NC	C	NC	C	NC	C	NC

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S15: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2040

Scenarios		Markets 2040		Innovation 2040		Austerity 2040		Lifestyles 2040	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	NC	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	C	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	NC	NC	C	NC	C	NC	C	NC
	CST	NC	NC	NC	NC	NC	NC	NC	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	NC	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	NC	NC	NC	NC	NC	NC
	H4	NC	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S16: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2045

Scenarios		Markets 2045		Innovation 2045		Austerity 2045		Lifestyles 2045	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	NC	NC	C	NC
	SCP	NC	NC	C	NC	NC	NC	C	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	NC	NC	C	NC	C	NC	C	NC
	CST	NC	NC	NC	NC	NC	NC	NC	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	C	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	C	NC	NC	NC	NC	NC
	H4	NC	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

Table S17: Compliancy of the strategies with respect to the domains of reliability-resilience-sustainability and multiple adaptation thresholds in the epoch ending in 2050

Scenarios		Markets 2050		Innovation 2050		Austerity 2050		Lifestyles 2050	
Objectives		CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding	CSO & Sewer flooding	CSO, Sewer, flooding & river flooding
Strategies	DN	NC	NC	NC	NC	NC	NC	NC	NC
	SCC	NC	NC	NC	NC	NC	NC	NC	NC
	SCR	NC	NC	C	NC	NC	NC	C	C
	SCP	NC	NC	C	NC	NC	NC	C	NC
	OT	NC	NC	NC	NC	NC	NC	NC	NC
	SS	NC	NC	C	NC	C	NC	C	NC
	CST	NC	NC	NC	NC	NC	NC	NC	NC
	CS	NC	NC	NC	NC	NC	NC	NC	NC
	H1	NC	NC	C	NC	NC	NC	C	NC
	H2	NC	NC	C	NC	NC	NC	C	NC
	H3	NC	NC	C	NC	NC	NC	C	NC
	H4	NC	NC	C	NC	C	NC	C	C

* C: Compliant
** NC: Non-Compliant (in grey colour)

S8. Detailed results on the assessment of strategies by the regret indices

S8.1 Results on regret levels in the multiple domains of resilience-sustainability

Table S18: Resilience-sustainability regret index in the epoch ending in 2020 and 2025

Level of regret in in the multiple domains of resilience-sustainability								
Strategies	Epoch ending in 2020				Epoch ending in 2025			
DN	0.817	0.847	0.735	0.679	1.000	1.000	0.754	1.000
SCC	0.719	0.619	0.632	0.531	1.000	1.000	0.653	1.000
SCR	0.342	0.273	0.262	0.261	0.306	0.289	0.282	0.240
SCP	0.528	0.452	0.464	0.294	1.000	0.449	0.452	0.386
OT	0.615	0.744	0.702	0.482	1.000	1.000	0.638	0.611
SS	0.513	0.544	0.451	0.406	0.512	0.479	0.476	0.436
CST	0.475	0.441	0.374	0.389	0.441	0.481	0.399	0.405
CS	0.561	0.592	0.592	0.659	0.756	0.766	0.617	0.747
H1	0.474	0.440	0.428	0.331	1.000	1.000	0.414	0.290
H2	0.435	0.425	0.356	0.315	0.413	0.416	0.368	0.349
H3	0.572	0.576	0.529	0.437	1.000	1.000	0.484	0.389
H4	0.265	0.199	0.230	0.293	0.217	0.175	0.147	0.255

Table S19: Resilience-sustainability regret index in the epoch ending in 2030 and 2035

Level of regret in in the multiple domains of resilience-sustainability								
Strategies	Epoch ending in 2030				Epoch ending in 2035			
DN	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SCC	1.000	1.000	0.814	1.000	1.000	1.000	1.000	1.000
SCR	1.000	0.616	0.259	0.168	0.684	0.235	0.263	0.175
SCP	1.000	1.000	0.422	0.345	1.000	1.000	0.419	0.320
OT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SS	0.768	0.526	0.456	0.407	0.459	0.463	0.432	0.394
CST	0.604	0.469	0.391	0.387	0.601	0.455	0.385	0.376
CS	1.000	1.000	0.775	0.752	1.000	1.000	0.763	0.750
H1	1.000	1.000	0.396	1.000	1.000	1.000	0.354	0.285
H2	1.000	0.695	0.386	0.304	0.716	0.359	0.364	0.301
H3	1.000	1.000	0.508	1.000	1.000	1.000	0.495	0.721
H4	0.540	0.178	0.163	0.216	0.529	0.177	0.169	0.195

Table S20: Resilience-sustainability regret index in the epoch ending in 2040 and 2045

Level of regret in in the multiple domains of resilience-sustainability								
Strategies	Epoch ending in 2040				Epoch ending in 2045			
DN	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SCC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SCR	0.693	0.223	0.239	0.165	0.703	0.213	0.192	0.140
SCP	1.000	1.000	0.421	0.297	1.000	1.000	0.396	0.303
OT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SS	0.436	0.456	0.407	0.406	0.468	0.455	0.382	0.386
CST	1.000	0.466	0.371	0.391	1.000	0.628	0.358	0.397
CS	1.000	1.000	0.770	0.754	1.000	1.000	1.000	0.759
H1	1.000	1.000	0.366	0.287	1.000	1.000	0.373	0.269
H2	0.724	0.355	0.348	0.296	0.380	0.348	0.314	0.292
H3	1.000	1.000	0.491	0.449	1.000	1.000	0.500	0.446
H4	0.205	0.188	0.157	0.185	0.226	0.194	0.142	0.180

Table S21: Resilience-sustainability regret index in the epoch ending in 2050

Level of regret in in the multiple domains of resilience-sustainability				
Strategies	Epoch ending in 2050			
DN	1.000	1.000	1.000	1.000
SCC	1.000	1.000	1.000	1.000
SCR	0.275	0.199	0.186	0.133
SCP	1.000	1.000	0.397	0.304
OT	1.000	1.000	1.000	1.000
SS	0.450	0.442	0.377	0.362
CST	1.000	0.477	0.360	0.405
CS	1.000	1.000	1.000	0.760
H1	1.000	1.000	0.388	0.288
H2	0.368	0.333	0.303	0.292
H3	1.000	1.000	0.505	0.445
H4	0.232	0.192	0.152	0.187

S8.2 Results on regret levels in the multiple domains of reliability-resilience-sustainability

Table S22: Reliability-resilience-sustainability regret index in the epoch ending in 2020 and 2025

Level of regret in in the multiple domains of reliability-resilience-sustainability								
Strategies	Epoch ending in 2020				Epoch ending in 2025			
DN	0.809	0.828	0.745	0.695	1.000	1.000	0.758	1.000
SCC	0.700	0.680	0.655	0.572	1.000	1.000	0.667	0.882
SCR	0.355	0.302	0.265	0.249	0.299	0.308	0.258	0.240
SCP	0.532	0.520	0.447	0.316	1.000	0.482	0.457	0.406
OT	0.608	0.755	0.724	0.529	1.000	1.000	0.668	0.523
SS	0.510	0.537	0.448	0.357	0.534	0.483	0.488	0.428
CST	0.459	0.371	0.326	0.281	0.627	0.427	0.365	0.360
CS	0.531	0.554	0.544	0.586	0.837	0.686	0.612	0.680
H1	0.468	0.493	0.429	0.341	1.000	1.000	0.430	0.285
H2	0.437	0.466	0.353	0.298	0.422	0.419	0.367	0.349
H3	0.573	0.612	0.527	0.440	1.000	1.000	0.535	0.382
H4	0.210	0.149	0.204	0.251	0.187	0.139	0.127	0.231

Table S23: Reliability-resilience-sustainability regret index in the epoch ending in 2030 and 2035

Level of regret in in the multiple domains of reliability-resilience-sustainability								
Strategies	Epoch ending in 2030				Epoch ending in 2035			
DN	1.000	1.000	0.924	1.000	1.000	1.000	1.000	1.000
SCC	1.000	1.000	0.745	1.000	1.000	1.000	1.000	1.000
SCR	1.000	0.744	0.235	0.170	0.789	0.490	0.249	0.171
SCP	1.000	1.000	0.429	0.356	1.000	1.000	0.416	0.334
OT	1.000	1.000	0.875	1.000	1.000	1.000	0.872	1.000
SS	0.845	0.522	0.469	0.410	0.639	0.456	0.432	0.381
CST	0.736	0.646	0.354	0.591	0.734	0.636	0.590	0.584
CS	1.000	1.000	0.712	0.835	1.000	1.000	0.842	0.833
H1	1.000	1.000	0.395	1.000	1.000	1.000	0.351	0.523
H2	1.000	0.797	0.389	0.303	0.811	0.573	0.379	0.306
H3	1.000	1.000	0.531	1.000	1.000	1.000	0.512	0.814
H4	0.383	0.149	0.157	0.194	0.373	0.145	0.154	0.177

Table S24: Reliability-resilience-sustainability regret index in the epoch ending in 2040 and 2045

Level of regret in in the multiple domains of reliability-resilience-sustainability								
Strategies	Epoch ending in 2040				Epoch ending in 2045			
DN	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SCC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SCR	0.795	0.482	0.219	0.151	0.802	0.475	0.197	0.133
SCP	1.000	1.000	0.408	0.307	1.000	1.000	0.403	0.306
OT	1.000	1.000	0.872	1.000	1.000	1.000	0.890	1.000
SS	0.624	0.433	0.403	0.374	0.645	0.427	0.385	0.357
CST	1.000	0.644	0.581	0.594	1.000	0.752	0.572	0.598
CS	1.000	1.000	0.846	0.836	1.000	1.000	1.000	0.839
H1	1.000	1.000	0.353	0.313	1.000	1.000	0.384	0.302
H2	0.816	0.570	0.331	0.283	0.587	0.565	0.309	0.278
H3	1.000	1.000	0.503	0.482	1.000	1.000	0.523	0.467
H4	0.470	0.153	0.127	0.149	0.484	0.150	0.118	0.142

Table S25: Reliability-resilience-sustainability regret index in the epoch ending in 2050

Level of regret in in the multiple domains of Reliability-resilience-sustainability				
Strategies	Epoch ending in 2050			
DN	1.000	1.000	1.000	1.000
SCC	1.000	1.000	1.000	1.000
SCR	0.517	0.466	0.178	0.123
SCP	1.000	1.000	0.384	0.305
OT	1.000	1.000	0.877	1.000
SS	0.633	0.417	0.373	0.336
CST	1.000	0.651	0.573	0.603
CS	1.000	1.000	1.000	0.840
H1	1.000	1.000	0.393	0.311
H2	0.578	0.556	0.293	0.270
H3	1.000	1.000	0.529	0.462
H4	0.488	0.146	0.121	0.145

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